EVALUATION OF ENERGY SUPPLY-DEMAND BALANCE AND CO_2 EMISSIONS FROM THE TRANSPORT SECTOR IN TURKEY BASED ON TECHNOLOGICALLY DETAILED MARKAL BASED ENERGY MODELING

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B.S., Industrial Engineering, İstanbul Technical University, 2008

Submitted to the Institute for Graduate Studies in
Science and Engineering in partial fulfillment of
The requirements for the degree of
Master of Science

Graduate Program in Industrial Engineering
Boğaziçi University
2011

ACKNOWLEDGEMENTS

I would like to express my utmost gratitude to my supervisor Prof. İlhan Or for his guidance, forbearance, and encouragement. From the initial to the final level, his contributions, knowledge, and experience on the topic have facilitated the realization of this thesis. My grateful thanks also go to Assoc. Prof. Gürkan Kumbaroğlu who introduced me to the field of environmental studies.

Being a member of Ministry of Development (formerly State Planning Organization), special thanks should be given to Deputy Undersecretary Mr. M. Cüneyd Düzyol, General Director Mr. A. Latif Tuna, Head of Department Mr. Murad Gürmeriç, Planning Expert Mr. O. Olcay Güneği and my colleagues – Mr. Serdinç Yılmaz, Mrs. S. Yavuz Noyan and, Mr. İ. Çağrı Özcan in particular – who supported and helped me in many ways throughout the preparation of this thesis.

Besides, I would also like to thank my friend Kemal Dinçer Dingeç for his significant assistance and TÜBİTAK for their financial support during my graduate study.

Most importantly, I thank to my family for their invaluable support throughout my life.

ABSTRACT

EVALUATION OF ENERGY SUPPLY-DEMAND BALANCE AND CO_2 EMISSIONS FROM THE TRANSPORT SECTOR IN TURKEY BASED ON TECHNOLOGICALLY DETAILED MARKAL BASED ENERGY MODELING

Global warming has been one of the main concerns all over the world in the last decades and this phenomenon gave rise to the increase in the studies and research on GHG (Greenhouse Gases) emissions, CO_2 in particular. This study examines CO_2 emissions from the transport sector in Turkey based on a MARKAL-Turkey Energy Model where CO_2 emissions, investment costs, and energy demands are estimated for each 5-year time period between 2006 and 2051. The transport sector is analyzed in four main modes, namely road, rail, maritime, and air transport. The main modes are further detailed into 23 sub-modes (vehicle types) and the data regarding these sub-modes have been collected from various governmental institutions and non-governmental organizations. For the analysis of CO_2 emissions, three groups of scenarios are defined in the study; the emission reduction scenarios, modal shift scenarios, and auto efficiency with fuel price scenarios. Each scenario group consists of a base and two alternative cases. By the combination of these cases, a total of 27 scenarios are created. Examining the results of the scenarios, the total CO_2 emissions and energy consumptions are presented by tables and figures with respect to fuel types. In addition, fuel consumptions and investments are also assessed with respect to sub-modes and time periods. In conclusion, all scenarios are compared with each other and the results are presented.

ÖZET

TÜRKİYE'DE ULAŞTIRMA SEKTÖRÜ ENERJİ ARZ-TALEP DENGESİNİN VE CO_2 EMİSYONLARININ TEKNOLOJİK DETAYLI MARKAL ENERJİ MODELİYLE DEĞERLENDİRİLMESİ

Küresel ısınma geçen on yıllar içerisinde tüm dünyada en dikkat çeken konulardan biri haline gelmiş ve bu olay başta CO_2 olmak üzere sera gazı emisyonları üzerine yapılan çalışma ve araştırmaların artmasına neden olmuştur. Bu çalışmada, 2006-2051 yılları arasında Türkiye'de ulaştırma sektöründen kaynaklı CO_2 emisyonları, MARKAL-Türkiye enerji modeli kullanılarak yatırım maliyetleri ve enerji taleplerinin de hesaplanması suretiyle 5 yıllık dönemler halinde incelenmiştir. Ulaştırma sektörü karayolu, demiryolu, denizyolu ve havayolu olmak uzere 4 ana modda incelenmiştir. Daha sonra ana modlar 23 alt mod (araç tipi) olarak detaylandırılmış ve bu alt modlar ile ilgili veriler çeşitli kamu kurumlarından ve sivil toplum kuruluşlarından temin edilmiştir. Çalışmada, CO_2 emisyonlarını analiz etmek için emisyon azaltım senaryoları, modal değişim senaryoları ve otomobil verimliliği ile yakıt fiyatının birlikte olduğu senaryolar olmak üzere üç senaryo grubu tanımlanmıştır. Her bir senaryo grubu baz ve 2 alternatif durumdan oluşmaktadır. Bu durumların birbiriyle olan kombinasyonlarından toplam 27 senaryo oluşturulmuştur. Senaryoların sonuçları incelenerek salınan CO_2 emisyonları ve tüketilen enerji miktarları yakıt türlerine göre tablo ve grafiklerle sunulmuştur. Ayrıca, yakıt tüketimleri ve yapılan yatırımlar da alt-modlar ve dönemler itibarıyla değerlendirilmiştir. Sonuç kısmında, bütün senaryolar birbiriyle karşılaştırılmış ve elde edilen sonuçlar sunulmuştur.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS/ABBREVIATIONS

BAU	Business As Usual
CCS	Carbon Capture and Storage
CNG	Compressed Natural Gas
DWT	Dead Weight Tons
ETSAP	Energy Technology Systems Analysis Program
EU	European Union
EJ	Exajoule
GDP	Gross Domestic Product
GHG	Greeen House Gas
GMM	Global Multi-regional MARKAL
Gt	Giga-Tons
GT	Gross-Tons
GWh	Giga-Watt Hours
IBB	Istanbul Metropolitan Municipality
ICE	Internal Combustion Engine
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
KGM	General Directorate of Highways
Kt	Kilo-tons
LPG	Liquefied Petroleum Gas
Mt-CO_2	Million tons of CO_2
Mtoe	Million tons of oil equivalent
NGCC	Natural Gas Combined Cycle
PC/SCPC	Pulverized Coal/Super Critical Pulverized Coal
PJ	Petajoule
PPM	Parts per million
PPMV	Parts per million by volume
RES	Reference Energy System
SPO	State Planning Organization
TA	Domestic Passenger Airplanes

TB1	Intercity Buses
TB2	Intracity Buses
TB3	Minibuses
TC1	Private Cars (1000-1400 cc)
TC2	Private Cars (1400-1600 cc)
TC3	Private Cars (1600-2000 cc)
TC4	Private Cars (2000+ cc)
TCDD	Turkish State Railways
TCX	Taxies
TEU	Twenty-feet Equivalent Unit
TH1	Heavy Trucks
TH2	Trailers
THY	Turkish Airlines
TIDOF	Intercity Ferry Boats
TIDOP	Urban Passenger Boats
TL	Light Trucks
TOE	Tons of oil equivalent
TPES	Total Primary Energy Supply
TRF	Freight Trains
TRH	High-Speed Passenger Trains
TRM	Mainline Passenger Trains
TRMET	Urban Rail Systems
TRS	Suburban Trains
TSDY	Bulk-Carrier Ships
TSKT	Container Ships
TSKY	Dry-Cargo Ships
TSTK	Tankers
TUIK	Turkish Statistical Institute
UNFCCC	United Nations Framework Convention on Climate Change
US	United States

1. INTRODUCTION

The earth has been a balanced, stable and reliable source of food, water and air for the human being for more than 10000 years. But in the last 300 years, beginning by the industrial revolution, this delicate balance has been increasingly tempered by human activities. As a result of these activities, global warming and climate change have been the major environmental concerns of the global community especially in the last few decades. The main reason for global warming and climate change is considered as the enhancement of the greenhouse effect which can be defined as the increase in the temperature of the atmosphere and the earth's surface caused by the entrapment of the solar energy (carried by light rays and electromagnetic waves) by the GreenHouse Gases (GHGs) [1].

The greenhouse gases primarily consist of the following: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CF_xCl_x), tropospheric ozone (O_3) and water vapor [2].

In fact, the greenhouse effect is a natural phenomenon which allows the continuation of life on earth by keeping the earth's surface temperature at about 15 degrees Celsius. The 45% of the total energy coming from the sun is either reflected or absorbed by the atmosphere. The rest reaches to the earth's surface, but again 4% is reflected back to space. Thus, the net energy absorbed by the earth's surface accounts for the 51% of the total energy coming from the sun. This amount is essential for the life on earth in heating of the land masses, heating and, evaporation of the oceans, and photosynthesis of the green plants. After being heated by the sun, the earth itself becomes an energy radiating source and it emits infrared radiation to space. This step gives rise to the greenhouse effect. The infrared radiation is trapped by the greenhouse gases and 90% of this trapped radiation is reflected back to earth. This process continues until the energy is totally absorbed by the earth. By this phenomenon the atmosphere and the earth's surface are heated and life could exist on the planet [2].

As mentioned above, various human activities led to the increase in the emissions of the greenhouse gases, especially after the industrial revolution. In Figure 1.1, concentrations of CO_2, N_2O and CH_4 gases in the atmosphere are presented and it can be seen that, beginning with the year 0, graphs follow a uniform trend but after the industrial revolution the concentrations for all gases increase dramatically. The concentration of the carbon dioxide gas was about 280 parts per million (ppm) in 1700s, but by 2005, it reached to 379 ppm. Likewise, N_2O and CH_4 concentrations rose with similar trends [3].

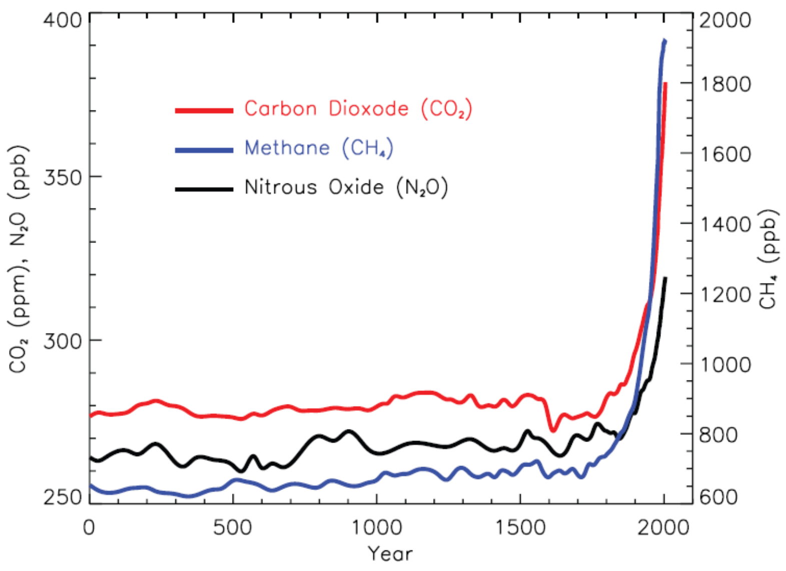

Figure 1.1. Concentrations of GHGs from 0 to 2005 [3].

The enormous increase in GHGs is a threat for the heat balance and the climate patterns on earth. CO_2 is the most significant gas regarding greenhouse effects and it is responsible for about 55% of the global warming due to this effect. The main contributor for the CO_2 emissions is the fossil fuel combustion processes (due to the many industrial and residential activities all over the globe), which account for 65% of the additional CO_2 emissions existing in the atmosphere [2].

Additionally, according to the International Energy Agency (IEA), global CO_2 emissions from fossil fuel combustion were realized as 29.4 Giga-tons (Gt) in 2008 [4], whereas it was just 14.1 Gt in 1971 [5]. This shows that the total CO_2 emissions had increased more than 100% in just 37 years.

It is believed that the earth's temperature has risen by 0.3-0.6 degrees Celsius in the last century and it is further estimated that within 50 years, the average temperature will be

1-3 degrees Celsius higher than today [2]. Moreover, according to the Intergovernmental Panel on Climate Change (IPCC), it is expected that the sea level will increase by 18-59 centimeters in the 21st century and the average surface temperature will be 1.8 to 4.0 degrees Celsius higher in the 2090-2099 period than that of the 1980-1999 [6]. The potential impacts of such changes on global climate patterns, agricultural output, natural phenomena and suitability and sustainability of global environment for the six billion plus (and growing) human population, could be extremely negative.

Since global warming and climate change are considered as major problems in the world, it directed the countries towards cooperation and thinking on precautions to mitigate GHG emissions. With this aim, in 1979, the First World Climate Conference was held by World Meteorological Organization in Geneva. As a result of this conference the World Climate Programme and the World Climate Research Programme were established. Besides, it led to the creation of the IPCC in 1988. Likewise, in 1990, the Second World Climate Conference was held and a Ministerial Declaration was approved. Consequently, in 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1994. After a long period of negotiations, Turkey became party to the UNFCCC in 2004 as an Annex-I country [6,7].

Additionally, in 1997, the Kyoto Protocol was signed and entered into force in 2005. With this protocol Annex-B countries (Annex-I countries of the UNFCCC) agreed to reduce their GHG emissions by 5% over the period 2008-2012, compared to 1990 levels. Turkey ratified the Kyoto Protocol in 2009. But, since Turkey was not party to the UNFCCC, while the negotiations for the protocol were carried on, it is not listed as an Annex-B country in the protocol. Therefore, Turkey did not commit itself to any specific emission targets like other members [8].

On the other hand, when GHG emissions resulting from fossil fuel combustion activities are investigated, it can be seen that (as of 2008) the two sectors, electricity and heat generation and transport, are responsible for 63% of the total CO_2 emissions in the world and the transport related emissions are realized as 6.6 Gt with a share of 22%. The sectoral breakdown of global CO_2 emissions is presented in Figure 1.2. These data prove the significance of the transport sector in the overall emissions from fossil fuel combustion in the world [4].

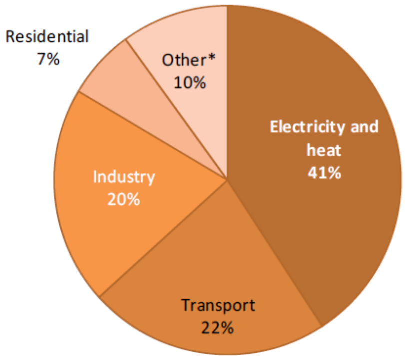

Figure 1.2. Global CO_2 emissions from fuel combustion by sectors in 2008 [4].

When the fossil fuel combustion activities in Turkey are focused on, it can be seen that (as of 2009), total CO_2 emissions from fuel combustion are realized as 271.1 million tons, with the electricity generation sector leading (at 102.5 tons and 37.8%), the industrial sector following (at 55.1 tons and 20.3%) and the transport sector being the third largest emission source (at 46.7 tons and 17.2%) [9]. Figure 1.3 presents the sectoral breakdown of the emissions from fossil fuel combustion in Turkey for the year 2009.

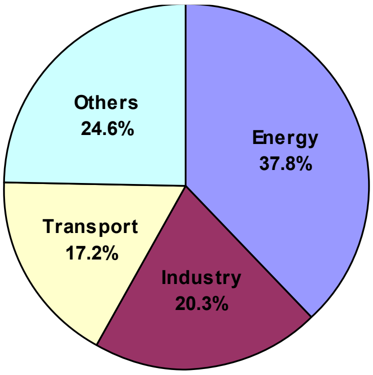

Figure 1.3. Turkey's sectoral CO_2 emissions from fossil fuel combustion in 2009 [9].

As displayed in Figure 1.3 the transport sector is one of the main contributors to the CO_2 emissions in Turkey. This is because the demand for energy in the transport sector is mostly (94%) met by combustion of fossil fuels [5], while the emission factors mainly depend on motor efficiencies. Thus, in order to reduce the negative environmental effects caused by the vehicles, research and development efforts are being made in all transport industries to manufacture more fuel-efficient vehicles than the conventional ones used today [10].

But, in addition to the technological improvements, factors like development and income levels, transport policies and strategies, transport infrastructure, public awareness, driving habits, training and education are also very important in reducing emission levels in the transport sector.

Moreover, academic studies on the CO_2 emissions from the transport sector are crucial for understanding the factors contributing to the overall emissions and evaluating the potential precautions to control emissions from the transport sector.

With this objective in mind, in this thesis, it is aimed to analyze the overall CO_2 emissions and especially the emissions from the transport sector in Turkey by using a MARKAL (MARket ALlocation) based national level energy model. MARKAL is a dynamic linear optimization modeling system which minimize the total discounted energy system cost over a time horizon in a specific region (or regions) while satisfying the energy supply-demand balance and various pre-defined or user defined constraints. The model is based on a Reference Energy System (RES), which is a framework of the energy system from the extraction of the energy sources to the consumption of demand sectors.

The model used in this study is set up for the planning horizon 2006-2051 and the analysis is conducted in nine five-year periods. The overall model is actually developed in the earlier studies, while the transport sector is fully overhauled and greatly expanded in this study. The transport sector is analyzed in four main transport modes: road transport, rail transport, maritime transport and air transport. These modes are further detailed into 23 sub-modes and the model data regarding these sub-modes are compiled from various state institutions, private companies, and non-governmental organizations.

Beside the introduction chapter, this thesis consists of six chapters.

In the second chapter, the literature on energy and environment modeling on national and sectoral levels using the MARKAL Modeling approach is presented. Additionally, other modeling approaches (beside the Markal approach) to energy and emissions planning and analysis are also presented.

In the third chapter, the general situation regarding energy and environment is introduced for both the world and Turkey. The energy demands and GHG emissions are presented with sectoral breakdown. Besides, the evolution of transport sector in Turkey is studied in detail. The status on the main transport modes for both freight and passenger are depicted with statistical data and graphs.

In the fourth chapter, the MARKAL Energy Model is presented with the primary assumptions and the formulations underlying the model. In addition, the MARKAL-Turkey Model is introduced.

The fifth chapter covers the methodology used and the assumptions made specifically for the transport sector in the MARKAL-Turkey model.

In the sixth chapter, the base scenario (corresponding to the current situation and future policies and expectations under the assumption of no major changes in the basic strategies and technologies) and the alternative scenarios (featuring major changes in strategies and technologies regarding emission limitations, transport policies and technologies) are discussed and their results are presented and interpreted.

Finally, in the seventh chapter, all the findings of the work are summarized with closing remarks and ideas for future studies.

2. LITERATURE SURVEY

Ichinohe and Endo [11] investigate the CO_2 emissions from the passenger-car sector in Japan from 1988 to 2032 by using a MARKAL model. Although, in the Kyoto Protocol, Japan has promised a 6% reduction in GHGs and a 17% increase in transportation related CO_2 emissions by 2010 (compared with 1990), the transport related emissions already increased by 23% between 1990 and 2001. Next, in order to reduce the CO_2 emissions, the authors aim to find the most cost-effective vehicle mix for passenger-cars leading to 50% savings in transport related CO_2 emissions and the necessary subsidy to reach that vehicle mix. In the study, under the no constraint case, the energy consumptions of the gasoline based internal combustion engine (ICE) vehicles keep growing. Whereas, under the “8% CO_2 emission reduction” case, the energy consumptions of the gasoline based ICE vehicles are reduced by about 50% by the year 2030 (compared to the level in 1990), while hybrid-electric vehicles are introduced in the market and its share in passenger-car sector reaches 62% (in 2030). The highest necessary subsidy value is reached in 2020 with 1.2 billion $/year and it is concluded that annual carbon tax revenue of 31 US$t-C from passenger-car sector will be sufficient to finance the subsidies.

Gül *et al*. [12] develop a Global Multi-regional MARKAL model (GMM) for alternative fuels in the personal transport sector, aiming to analyze factors for their deployment, focusing particularly on biofuels and hydrogen. The planning horizon in this GMM model is set for 100 years, consisting of 10 periods for 2000-2100. The model covers eight demand sectors but the transportation sector is analyzed in greater detail for six regions which are as follows; Western Europe (WEUR), North America (NAM), Latin America, Middle East and Africa (LAFM), Former Soviet Union and Eastern Europe (EEFSU), Asia and Other OECD Countries (OOECD). In the base scenario (with no limitations or constraints), CO_2 emissions increase continuously and reach 21 Gt of carbon per year by 2100, accounting for an atmospheric CO_2 concentration of 770 ppmv. Next, three more stringent scenarios (650, 550 and 450 ppmv) are analyzed. . In the 650 ppmv scenario the market share of biofuel hybrids and biofuel ICE vehicles increase. Under more stringent climate policies, the share of biofuels gradually decreases and hydrogen fuel cell vehicles dominate the market. In the most stringent scenario hydrogen production reaches 171 Exajoule (EJ) by the year 2100.

Contreras *et al*. [13] use the MARKAL approach to model energy consumptions by vehicle and fuel types in the road transport sector of the Madrid Region between the years 2010 and 2050. The vehicles are classified as buses, cars, vans, two and three wheeled vehicles, light, medium and heavy trucks. In the model three scenarios are studied based on the average annual growth rate for transport sector; a base scenario with 2.5% and two alternative scenarios with 1.2% (minimum) and 3.7% (maximum). The results highlight that the current energy sources will change dramatically in the period 2010-2050. In the minimum growth scenario, conventional fuels supply about half of the consumption, while the rest being supplied by alternative fuels and hydrogen. In the base scenario, hydrogen supply more than 50%, alternative fuels 25% and conventional fuels 25%. In the maximum growth scenario, more than 75% is covered by hydrogen and the rest by alternative fuels.

Changhong *et al*. [14] analyze Shangai, which is one of the fastest growing cities in the world, with a MARKAL based model forecasting energy consumptions and emissions of air pollutants for the period 1995-2023. The model covers 5 energy demand sectors, including transportation, and up to 30 sub sectors including aviation, shipping and highway transportation. In the study, a Business As Usual (BAU) scenario and two alternative scenarios (EP1 and EP2) are analyzed in which coal use in the power plants is capped at 50 and 45 million tons per year, respectively. The results show that due to the constraints on coal, the share of coal-fired power plants declines from 41% in 1995 to 20% in 2020, and the share of natural gas increases to 13% as a substitute energy supply. The results of this study indicate that (by 2020) the SO_2 emissions decline from 960 thousand tons per year (in the BAU scenario) to 460 thousand tons and 440 thousand tons (in EP1 and EP2), whereas CO_2 emissions decline from 230 million tons (in the BAU scenario) to 174 million tons and 168 million tons (in EP1 and EP2).

Ko *et al*. [15] study CO_2 mitigation scenarios in the power sector in Taiwan using the MARKAL-MACRO approach to analyze economic effects and the optimal investment alternatives for the scenarios created for CO_2 mitigation. In the BAU scenario, without any constraints, the PC/SCPC (Pulverized Coal/Super Critical Pulverized Coal) power plants dominate other fossil fuel power plants due to their lower costs. PC/SCPC share in electricity generation is more than 70% in 2050 and the share of NGCC (Natural Gas Combined Cycle) is 22%. Beginning by 2020, the share of nuclear power plants decreases year by year. Lastly, because of high costs and low efficiencies, fossil fuel power plants with Carbon Capture and Storage (CCS) do not exist in BAU scenario. The proposed alternative scenarios are; Rf1 (constraininig the CO_2 emissions in 2050 to 70% of 2000 level), Rt4 and Rt5 (those constrain the CO_2 emissions in 2050 to 70% and 80% of 2005 level), respectively. From the study, it can be concluded that in order to develop while keeping emissions under desired levels, Taiwan should definitely implement nuclear power plants for power generation.

Yeh *et al*. [16] use a MARKAL model to investigate the CO_2 mitigation policies on the light-duty transportation sector in the period 2010-2050 in the United States (US). In the study only CO_2 emissions are analyzed due to its share (about 84%) in total GHG emission of the US. Also the analysis is much more detailed on light duty vehicles since they are responsible for nearly half of the emissions in the transportation sector. The authors use two sets of scenarios; the ones limiting CO_2 emissions for the whole economy and the ones limiting emissions both all sectors and the transport sector. The mitigation rates in the constraints range from 10% to 50%. These scenarios show that limiting CO_2 emissions leads to sharp decreases in the number of gasoline vehicles and increase in the number of hybrid and ethanol based vehicles. Besides, the authors suggest four strategies to mitigate transport related CO_2 emissions; energy intensity reduction, fuel switching, lowering the global warming intensity of transportation fuels and finally modal change.

Rosenberg *et al*. [17] argue that since the Norwegian energy system heavily depends on hydro power and electricity, if any precautions are to be taken to reduce CO_2 emissions, the main target ought to be the transportation sector. For this purpose the authors investigate the market penetration for hydrogen fueled vehicles in Norway by using a MARKAL model for three regions during the period 2005-2050. A base scenario and 5 alternative scenarios analyze issues such as taxation policies, CO_2 reduction policies, technology costs and fuel costs. It is concluded that hydrogen fueled vehicles can be a competitive alternative in the future. These vehicles are expected to enter the market in 2020 and reach 100% penetration by 2035. Besides it is seen that in industrial regions and in the regions close to energy sources, the penetration of hydrogen vehicles are faster due to the reduced production costs and high resource availability.

Contaldi *et al*. [18] evaluate the effectiveness and potential of hydrogen as a means for tackling environmental issues and CO_2 mitigation. In their study, the MARKAL-Italy model, which was developed in the nineties, is used as a basis and 40 additional hydrogen technologies are added on, in order to analyze the deployment of hydrogen in four end use areas, such as transport, refineries, electricity generating plants and generation of heat. A baseline and an alternative scenario, which includes policies aiming at deployment of hydrogen, result in a total of two million vehicles stock in 2030. In the base scenario, hydrogen technology is not used in the transport sector, but in the alternative scenario hydrogen vehicles are responsible for 25% of the total mileage in 2040.

Schäfer and Jacoby [10] deploy a MARKAL model in evaluating the penetration of more efficient and clean technologies to the US transport sector, under a base and two alternative scenarios. These alternative scenarios are: The Kyoto Protocol limitation which requires 7% less emission in 2010 compared with 1990 and a more stringent scenario that consist of further 7% tightening beyond the Kyoto Protocol. The vehicle technologies analyzed in the study are classified according to their efficiencies and retail prices. In the order of efficiencies, they are named as: Fleet 95, BLV, ZeroCost, LoCost, PowTrn etc. In the base scenario, only the zero cost technology enters the passenger car market beginning in the year 2005. In the Kyoto scenario, the ZeroCost vehicles enter the market in 2000, whereas the LoCost vehicles enter the market in 2005 and gradually decrease after 2020. Additionally, the PowTrn1 vehicles enter the market in 2015 and increase their share until 2030. Finally, in the revised Kyoto scenario LoCost vehicles begin to decrease lose their share after 2015, and PowTrn1 and PowTrn2 vehicles enter the market in 2010 and 2015, respectively.

Shakya and Shrestha [19] investigate the environmental benefits of modal shift in the transport sector to electrified mass transport systems in a part of the land transport services in Nepal, a country rich in hydropower potential. For the period 2015-2050, they use a MARKAL model for evaluating the transport sector in two region of Nepal, Kathmandu and the rest. A base and additional five alternative scenarios are discussed in the study in order to observe the effects of model shift on both the environment and the economy. According to the results, transport related CO_2 emission in the base and the alternatives scenarios follow a declining trend, 459, 427, 408, 397, 409, and 389 million tons, respectively. Additionally, in the alternative scenarios the cumulative imported energy to be used in transport during 2005-2050 declines at least 6.3% and 14.6% in the most stringent case.

Haldenbilen and Ceylan [20] use a Genetic Algorithm based Transport Energy Demand Estimation (GATEDE) model to analyze transport energy demand in Turkey until the year 2020. The model needs population, Gross Domestic Product (GDP) and vehicle-km data as inputs. Three forms of models are developed to find the best fitting one for the data of 1970-2000 and it is found out that the quadratic form is the best one. The vehicles kilometers are calculated by “the car equivalent” approach in which all transport modes’ vehicle kilometers are converted to car-kilometers. After estimating the transport demand, three alternative scenarios are studied consisting of reduction in car usage by 10-20%, reduction in goods transport by 10-20% and finally reduction in car usage and goods transport together by 10% between the years 2002 and 2020. These scenarios indicate that under the assumption of 10-20% reduction in car usage (with respect to the base scenario) energy savings are calculated as 8.74% and 17.17%, whereas under the assumption of 10-20% reduction in goods transport the energy savings are 2.49% and 4.96%. Finally, under the 10% reduction in both the car usage and goods transport scenario, the estimated energy saving is 11.5%.

Similarly, Ceylan *et al*. [21] use the Harmony Search Transport Energy Demand Estimation (HASTEDE) model to evaluate the energy demand of Turkey until the year 2025. HASTEDE model requires population, GDP and vehicle-km input data like GATEDE model mentioned in [20].

Arslan *et al*. [22] focus on the fuel trends and policies and also on the history of alternative fuels for transport sector in Turkey. They give statistical data about the consumption of main fuel types used in transport sector and compare them with some developed countries and European Union (EU) countries. According to this study, the Turkish energy market has a highly centralized and state run character and especially the development of alternative fuel market is harmed by the policies and measures applied by the governments. The natural biofuel potential is also analyzed in the study and it is concluded that despite the immature nature of the alternative fuel market in Turkey, there is a very high potential in bio-fuel production and a comprehensive program is required to activate the inert agricultural potential for the purpose of bio-fuel production.

Soylu [23] estimates the emissions from road transport for the year 2004 using the COPERT III methodology. Beside CO_2 emissions, the model also calculates CH_4, N_2O, CO PM and SO_2, emissions separately for urban, rural and highway driving modes. Data regarding the fuel consumption for the road transport, max and min ambient temperatures, fleet data, introduction of emission regulations, mileage distribution and average vehicle speeds are required for the model as input data. For vehicle types, passenger cars, light duty vehicles, heavy duty vehicles, buses, mopeds and motorcycles are analyzed in the model. Among these types the passenger cars are identified as the main emission source in the transport sector. In conclusion, the author suggests four emission reduction strategies such as, 10% fleet renewal, shift to public transport, faster urban traffic and shift to four-stroke engines in mopeds and motorcycles. The results show that if some of these policies can be implemented, a reduction of up to 10% can be achieved in GHG emissions from road transport.

Kumbaroglu [24] decomposes Turkey's CO_2 emissions into electricity, manufacturing, transportation, household and agriculture sectors over 1990-2007 by using the refined Laspeyres method. In the study, it is concluded that in transport, electricity and manufacturing sectors scale effect, in household sector electrification and modernization, finally in the agricultural sector mechanization and increased output are the main contributors to CO_2 emissions.

Kumbaroglu and Arikan [25] evaluate the factors affecting the carbon emissions of Turkey. The study is conducted from both the national, household and personal aspects. The national aspect covers the regional and sectoral emissions of Turkey and their comparative status with the European Countries. Household and personal aspects cover the decomposition of the emissions by taking lifestyle, region and income level factors into account. Additionally, it covers the evaluation of the effects that can be seen on the CO_2

emissions when the people's habits are changed without discomforting their lifestyles. The study shows that the CO_2 emissions differ significantly by geographic regions' climatic, demographic and characteristic features.

In addition to these references, Lise [26] decomposes Turkey's CO_2 emissions for the transport, agriculture, industry and service sectors, over the period 1980-2003 and it is concluded that the economic growth is the main contributor of CO_2 emission in Turkey. Utlu and Hepbasli [27] assess energy utilization efficiencies in highway, maritime, airway and railway sectors in Turkey using energy and exergy analysis method. Ozturk and Acaravci [28] studies long run relationship between CO_2 emissions, energy consumption and economic growth in Turkey. Dincer and Elbir [29] estimates national GHG emissions from the railway sector in Turkey based on the methodology used in US Environmental Protection Agency's (EPA) Non-road engine and vehicle emissions study.

In conclusion, regarding related literature, it can be seen that directly applied CO_2 emission reduction scenarios are very common in academic studies. In such scenarios, alternative and cleaner technologies, such as hydrogen, electiricity and bio-fuels, are deployed in order to satisfy dictated emission constraints. Kyoto Protocol is especially referred for such emission reduction percentages. In addition, the impacts of modal shift scenarios are also assessed regarding the energy consumptions and CO_2 emissions and it is observed that modal shift can be an option for reducing both energy consumptions and CO_2 emissions of the transport sector. Lastly, the impact of external factors such as income, sectoral and economic growth rates, geographical differences between regions and people's habbits play significant role on the total and sectoral CO_2 emissions.

3. ENERGY, ENVIRONMENT AND TRANSPORT

Energy and environment are strongly intercorrelated issues. The environment provides natural resources as inputs for the energy sector. Processing these resources, the energy sector provides the primary energy supply, which is then transformed in many processes until being available for the end-users' service, for the final energy demand. On the other hand, these energy generation activities not only cause the depletion of the related resources, but also have many negative impacts on the environment through the release of many undesirable and harmful substances (in the form of gases, liquids and/or solids) into the environment. The primary focus of this study is on the emission of one of these undesirable gases, namely CO_2, into the environment, as a result of various energy generation and/or consumption activities.

Energy is used in all economic sectors for various purposes, such as power generation, residential, and transport needs, industrial activities and the supplies for this energy demand ranges from the coal used in power plants, to the fuel used in transport vehicles. As a result of the processes and transformations in these sectors, especially by the combustion of fossil fuels, CO_2 gases are emitted to the environment. CO_2 gases, like all other GHGs, trap the heat in the atmosphere and this causes global warming and finally climate change.

On the other hand, population and GDP also play a vital role on the evolution and development of energy related activities and CO_2 emissions. The similar trends of population and GDP are shown in Figure 3.1, along with the total primary energy supply and global CO_2 emissions.

Therefore, in this section, the general outlook of the energy sector and CO_2 emissions are elaborated for both the world and Turkey.

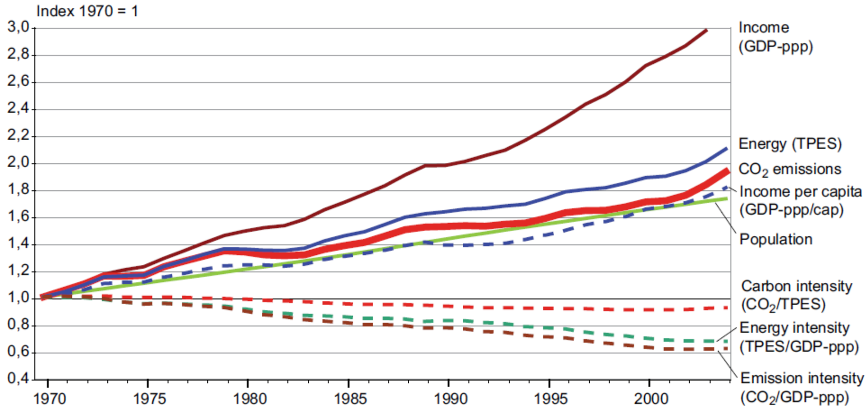

Figure 3.1. Relationship between energy, income, emissions and population [30].

3.1. Energy and Environment in the World

In this section a general outlook is taken to energy and environment in the world.

3.1.1. Energy

The global total primary energy supply (TPES) was realized as 6115 Million Tones of Oil Equivalent (Mtoe) in 1973. Oil was the main supplier of the total primary energy demand with 46.1%. Coal and Gas follow oil with 24.5 and 16.0% [31]. In 2008, the primary energy supply increased to 12267 Mtoe (about twice the level of 1973). But the share of oil in total energy supply decreased to 33.2%, while the share of coal and gas increased to 27.0 and 21.1%, respectively [31]. Figures 3.2 and 3.3 present the total primary energy supply trend with the share of fuel type over the period 1973-2008.

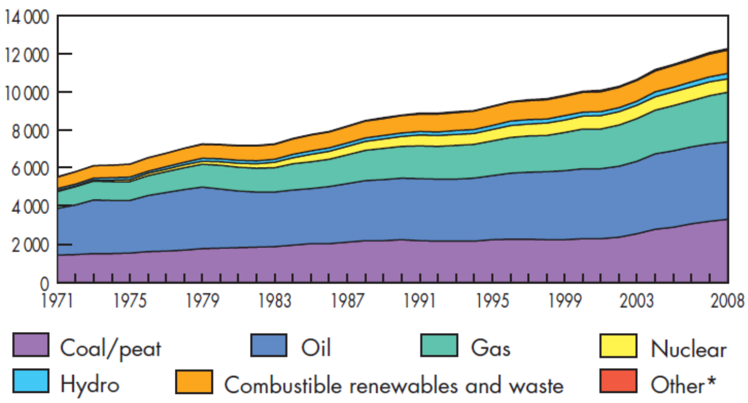

Figure 3.2. World total primary energy supply between 1971 and 2008 [31].

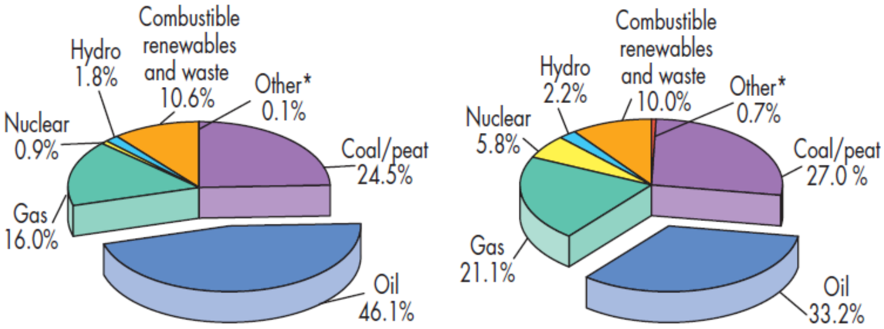

Figure 3.3. Fuel shares of the total primary energy supplies in 1973 and 2008 [31].

Regarding future energy demands, the IEA [32] considers three scenarios, namely new policies scenario, current policies scenario and 450 ppm scenario. The new policies scenario projects the future energy demand under the commitments and energy policies declared by the countries targeting the year 2020. For the future, the current policies scenario assumes no major changes in the countries' policies adopted as of 2010. The 450 ppm scenario includes the adoption of the most stringent policies by the countries targeting a maximum CO_2 concentration of 450 ppm and a global temperature increase of two degrees Celsius worldwide.

According to the IEA [32], in 2008, the world primary energy demand was realized as 12250 Mtoe. Under the new policies scenario, it is projected that the world primary energy demand will reach 16750 Mtoe by 2035 with an annual growth rate of 1.2% over 2008-2035. Under current policies and trends, it is estimated that the total primary energy demand will grow by 1.4% annually, reaching about 18050 Mtoe in 2035. Finally, the primary energy demand in 450 scenarios is projected to be 14920 Mtoe corresponding to an annual growth rate of 0.7%.

In Figure 3.4, the projected primary energy demand for the three mentioned scenarios are presented up to 2035 and in Figure 3.5, the shares of fuel types are displayed for the years 2020 and 2035, respectively.

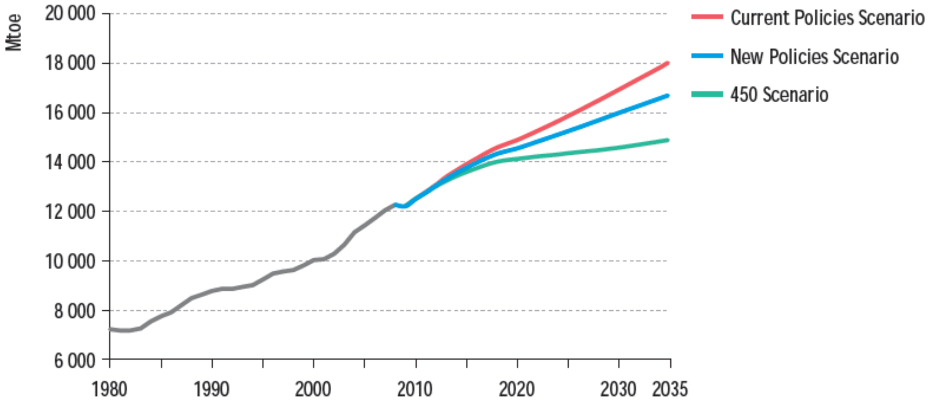

Figure 3.4. World primary energy demand by scenarios from 1980 to 2035 [32].

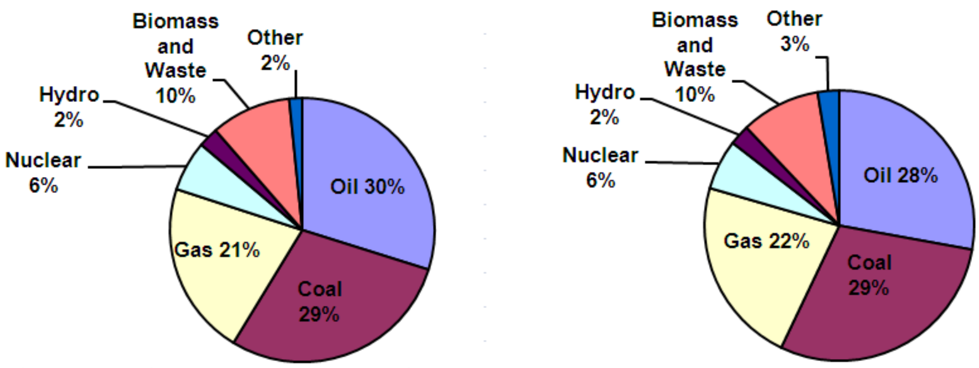

Figure 3.5. World primary energy demand by fuel types in 2020 and 2035 under current policies scenario [32].

3.1.2. Environment

Fossil fuels, which are the main contributors to the CO_2 emissions, have comprised the majority of the world primary energy supply. In 1971 the share of fossil fuels in primary energy supply was 86% [4]. Although, the share of fossil fuels dropped to 81% in 2008, they still remain as the main source of primary energy supply. Figure 3.6 presents the share of fossil fuels on the total primary energy supply and global CO_2 emissions. It can be seen that coal is the leading CO_2 source among fossil fuels with 43%, while it only supplies 27% of the total primary energy [4].

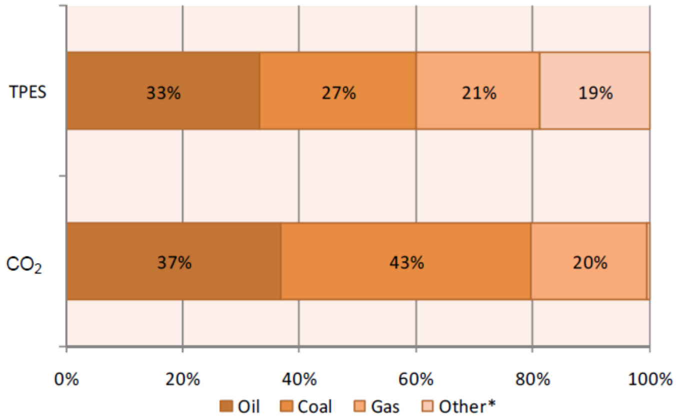

Figure 3.6. Share of fuel types in the world primary energy supply and CO_2 emissions in 2008 [4].

The emissions from fossil fuel combustion were realized as 15600 million tons of CO_2 (Mt-CO_2) in 1971. But it increased by 88% and reached to 29400 Mt-CO_2 in 2008 [31]. Figure 3.7 shows the trend of total CO_2 emission from fuel combustion by fuel type over the period 1971-2008.

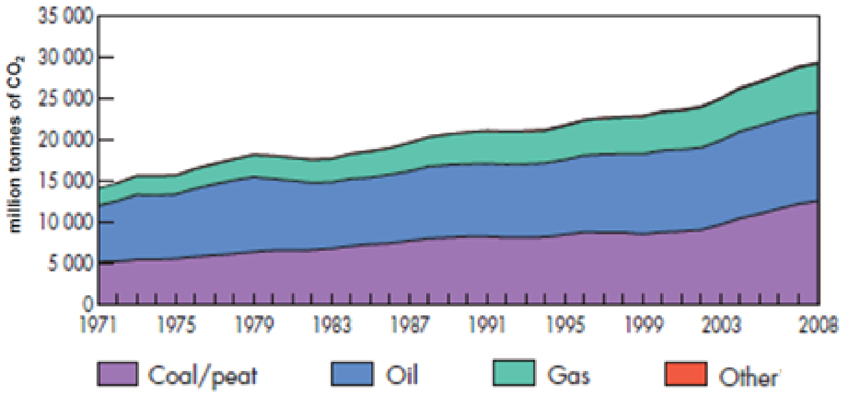

Figure 3.7. The global CO_2 emissions from fuel combustion by fuel types [31].

According to U.S. Energy Information Administration [33], the CO_2 emissions from fossil fuel combustion will continue to increase and reach 33.8 Mt-CO_2 in 2020 and 42.4 Mt-CO_2 in 2035.

The sectoral breakdown of emissions from fuel combustion show that, in 2008, of the total 29400 Mt-CO_2 emissions, electricity and heat production sector emitted 11987 Mt-

CO_2 (40%), manufacturing sector emitted 5943 Mt-CO_2 (20%) and transport sector emitted 6600 Mt-CO_2 (22%) [4].

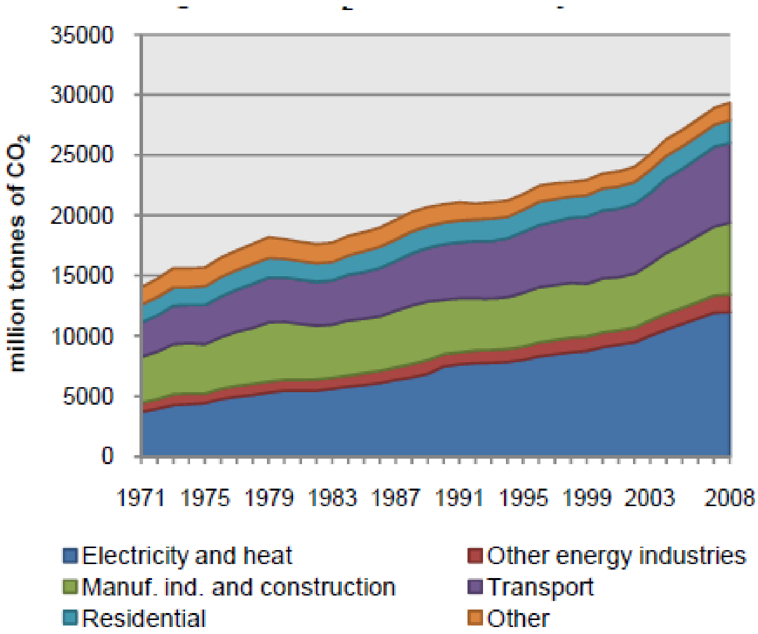

Figure 3.8. Global CO_2 emissions from fuel combustion by sectors [4].

3.2. Energy and Environment in Turkey

Turkey is a developing country with a population of more than 73 million. After the 2001 financial crisis, Turkey has shown a remarkable growing trend in the economy. Between the years 2003-2007 Turkey has grown 6.9% annually [34]. Furthermore, the GDP has grown 0.7%, -4.7% and 8.9% in 2008, 2009 and 2010 respectively [35]. This rapid growth over the last decade also greatly impacted the energy consumptions and CO_2 emissions in Turkey.

3.2.1. Energy

In Turkey, the long-term policies are included in the national development plans, which are prepared by the State Planning Organization (SPO). The latest plan is the ninth national development plan that covers the years 2007-2013. Additionally, the SPO also prepares Annual Programs consisting of the detailed short-term implementations and action of the main policies listed in the national development plans. In brief, the annual programs are the documents covering the short-term (annual) policies that are prepared consistent with the long-term policies in the national development plans.

In the ninth national plan, it is projected that the share of public investments will decrease, while the share of private sector investments will increase by incentivizing the private sector between 2007 and 2013 [36].

In the plan [36], it is further stated that, in 2006, the primary energy demand for Turkey was realized as 96.5 Mtoe and the electricity demand was realized as 171450 Giga-Watt Hours (GWh). In the period 2007-2013 it is forecasted that the primary energy demand will grow at a rate of 6.2% and the electricity demand 8.1%, annually. The forecasted values are presented in Table 3.1.

Table 3.1. Energy consumption forecasts for Turkey [36].

	2006	2013	Annual Growth
Primary Energy Demand (Mtoe)	96.5	147.4	6.2%
Electricity Demand (GWh)	171.4	295.5	8.1%

For the realization of the energy consumptions, the latest Annual Program is referred. Annual primary energy production and consumption values and annual electricity generation and consumption values are presented in 2011 Annual Program [35] for the period 2005-2011. The primary energy and electrical energy consumptions are presented in Figure 3.9 for the years 2000, 2005, and 2009. In addition, according to the program, realization estimate of the primary energy consumption for 2010 is 108.2 Mtoe, and the consumption forecast for 2011 is 114.3 Mtoe.

From the 2011 Annual Program [35], it can also be concluded that, in 2009, the domestic primary energy production covers only 29.5% of the total primary energy consumption, meaning that the dependency on imported energy is realized as 70.5%.

Beside the primary energy consumption, another globally used energy statistic is the final energy consumption, which means the net energy consumption calculated by the subtraction of the energy losses (those occur during the transformation processes) from the primary energy consumption [37].

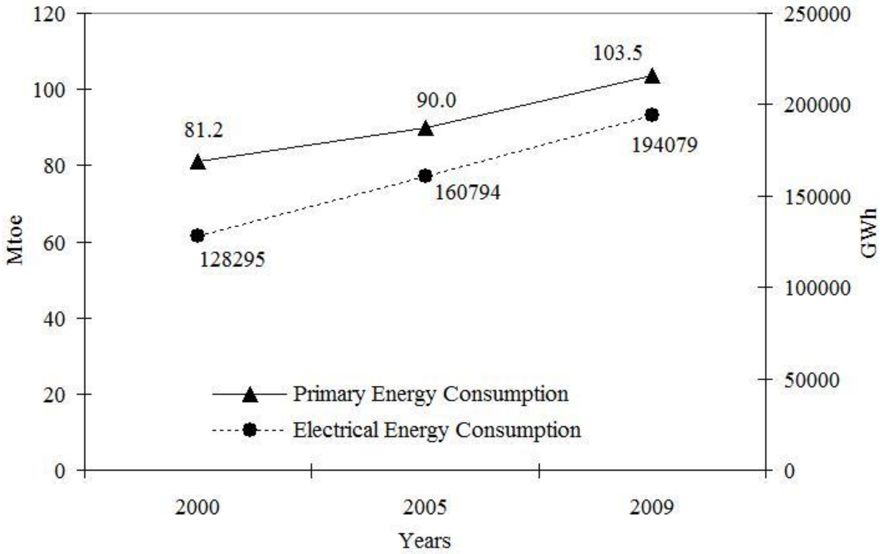

Figure 3.9. Energy consumption values for Turkey [35].

According to EuroStat, which is the official website for statistics of the EU, the final energy consumption in Turkey increased from 56.1 to 68.7 Mtoe between 2000 and 2009. The transport sector was responsible for 21.9% of the total final energy consumption in 2000 with 12.3 Mtoe, while in 2009 its share increased to 23.8% with 16.4 Mtoe [38]. The increase in the energy demand in transport sector is mostly due to the increase in the number of motor vehicles and the GDP. The transport sector is further analyzed in the next chapter.

From the energy and economy statistics it can be concluded that national energy needs increase day by day, and with the demand for fossil fuels, the GHG emissions (especially CO_2) are increasing in a similar trend.

Table 3.2. Final energy consumptions in Turkey (Mtoe) [38].

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total	56.1	50.4	55.3	59.2	61.2	63.6	69.6	74.1	73.0	68.7
Transport	12.3	11.8	12.7	12.7	13.0	13.5	15.0	17.1	16.4	16.4
Transport/Total	21.9%	23.4%	22.9%	21.4%	21.2%	21.3%	21.5%	23.1%	22.4%	23.8%

3.2.2. Environment

When the environmental aspects are focused on, it is seen that the growth rate of GHG emissions is at least as the growth rate of energy consumption. The GHG emissions are annually published by the Turkish Statistical Institute (TUIK). According to the TUIK [9], from 1990 to 2009, the total GHG emissions are nearly doubled and the total CO_2 emissions increased more than a fold. In 1990, total GHG emissions were 187.0 Mt-CO_2 equivalent (the unit for the GHG emissions other than CO_2 gases are converted to CO_2 units and defined as Mt-CO_2) and CO_2 emissions were 141.3 Mt-CO_2, and in 2009, these mentioned values realized as 369.6 and 299.1 Mt-CO_2, respectively [9].

Table 3.3. GHG emissions in Turkey [9].

	1990		1995		2000		2005		2009	
	Mt-CO_2	%	Mt-CO_2	%	Mt-CO_2	%	Mt-CO_2	%	Mt-CO_2	%
CO_2	141.3	75.6	173.9	73.2	225.4	75.9	259.6	78.7	299.1	80.9
CH_4	33.5	17.9	46.9	19.7	53.3	17.9	52.4	15.9	54.4	14.7
N_2O	11.6	6.2	16.2	6.8	16.6	5.6	14.2	4.3	12.5	3.4
F Gases	0.6	0.3	0.5	0.2	1.7	0.6	3.7	1.1	3.6	1.0
Total	187.0	100.0	237.5	100.0	297.0	100.0	329.9	100.0	369.6	100.0

Besides, from the sectoral breakdown of total GHG emissions [9], it is seen that fossil fuel combustion (includes power generation, transport, industrial activities and others) makes the highest contribution and it is responsible for 68%-75% of the total GHG emissions over the period 1990-2009. The agricultural sector, industrial processes and the waste sector follow fuel combustion. Table 3.4 shows the growth of GHG emissions by sectors.

Table 3.4. Sectoral GHG emissions in Turkey (Mt-CO_2) [9].

	1990	%	1995	%	2000	%	2005	%	2009	%
Fuel Combustion	132.1	70.6	160.8	67.7	212.5	71.6	241.8	73.3	278.3	75.3
Industrial Processes	15.4	8.3	24.2	10.2	24.4	8.2	28.8	8.7	31.7	8.6
Agriculture	29.8	15.9	28.7	12.1	27.4	9.2	25.8	7.8	25.7	7.0
Waste	9.7	5.2	23.8	10.0	32.7	11.0	33.5	10.2	33.9	9.2
Total	187.0	100.0	237.5	100.0	297.0	100.0	329.9	100.0	369.6	100.0

When the CO_2 emissions are focused on, it is seen that, fuel combustion is responsible for the 90% of the total CO_2 emissions [9]. Furthermore, since the transport sector is one of the main sectors energized by fuel combustion, it is important to analyze the breakdown of emissions from fuel combustion.

As it can be seen from Table 3.5 that the transport sector related CO_2 emissions increased from 25.9 to 46.7 Mt-CO_2 between 1990 and 2009, respectively. In contrast, its share in total emissions decreased from 18.4 to 15.6% within the same period [9]. This is mostly due to the higher growth rates realized in the power generation sector.

Table 3.5. Sectoral breakdown of the total CO_2 emissions in Turkey (Mt-CO_2) [9].

	1990	%	1995	%	2000	%	2005	%	2009	%
Fuel Combustion	126.7	89.6	155.3	89.3	207.0	91.9	236.3	91.0	271.1	90.6
Energy	34.0	24.1	47.3	27.2	76.8	34.1	88.5	34.1	102.5	34.3
Industry	37.5	26.6	42.0	24.1	59.9	26.6	67.4	26.0	55.1	18.4
Transport	25.9	18.4	32.8	18.9	34.9	15.5	40.5	15.6	46.7	15.6
Other Sectors	29.2	20.7	33.2	19.1	35.4	15.7	39.9	15.4	66.7	22.3
Industrial Processes	14.6	10.4	18.5	10.7	18.4	8.2	23.3	9.0	28.0	9.4
Mineral Production	13.7	9.7	17.5	10.1	18.1	8.0	22.6	8.7	28.0	9.4
Chemical Industry	0.8	0.6	0.9	0.6	0.2	0.1	0.6	0.2	0.0	0.0
Mining	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Total	141.3	100.0	173.8	100.0	225.4	100.0	259.6	100.0	299.1	100.0

When the emissions from the transport sector are investigated in detail, it can be seen that, while the emissions grow year by year, the share of transport sector did not increase that much and even decreased in the last decade. Figure 3.10 shows the transport related CO_2 emissions and their share in the total emissions between the years 1990 and 2009. It can be observed that the emissions grew faster in the periods 1991-1996 and 2004-2007. The rapid increase between 2004 and 2007 can be attributed to the 2001 economic crisis and the tax reduction incentives in automotive industry.

According to Kumbaroğlu and Arıkan [25], the CO_2 emissions from the transport sector vary from region to region depending on the region's economic, demographic and geographic conditions. In mountainous regions like the Black Sea and the Eastern Anatolia, the share of air transport is high due to the natural conditions and the distance to other regions. In the Marmara, Central Anatolia and Aegean regions, private car usage is higher due to the higher quality and availability of the transport infrastructure and higher income levels. In Figure 3.11, intercity modal split of the CO_2 emissions per capita for the people living in cities are depicted with respect to geographic regions of Turkey (which are Mediterranean, Eastern Anatolia, Aegean, South-Eastern Anatolia, Central Anatolia, Black Sea, and Marmara regions from top to down).

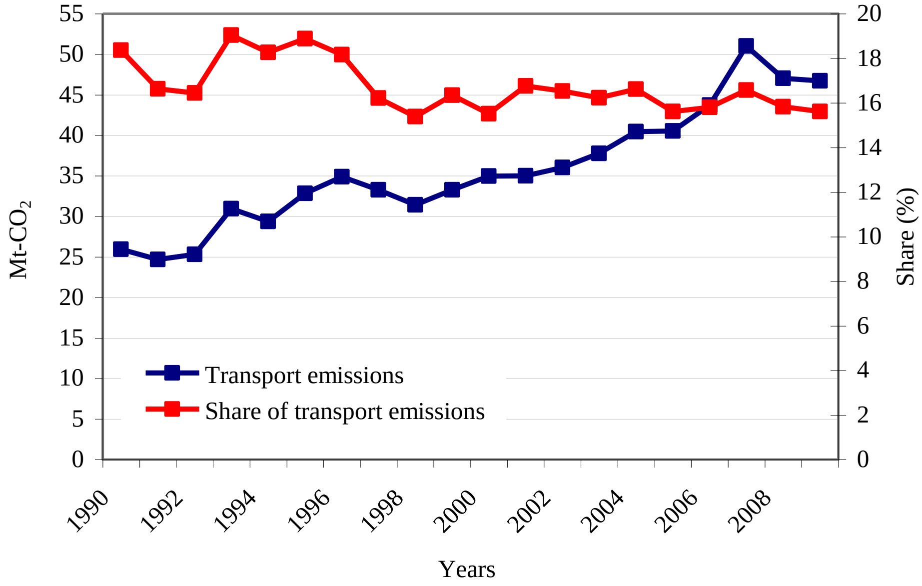

Figure 3.10. The CO_2 emissions of the transport sector in Turkey with its share in the total CO_2 emissions of Turkey (Mt-CO_2) [9].

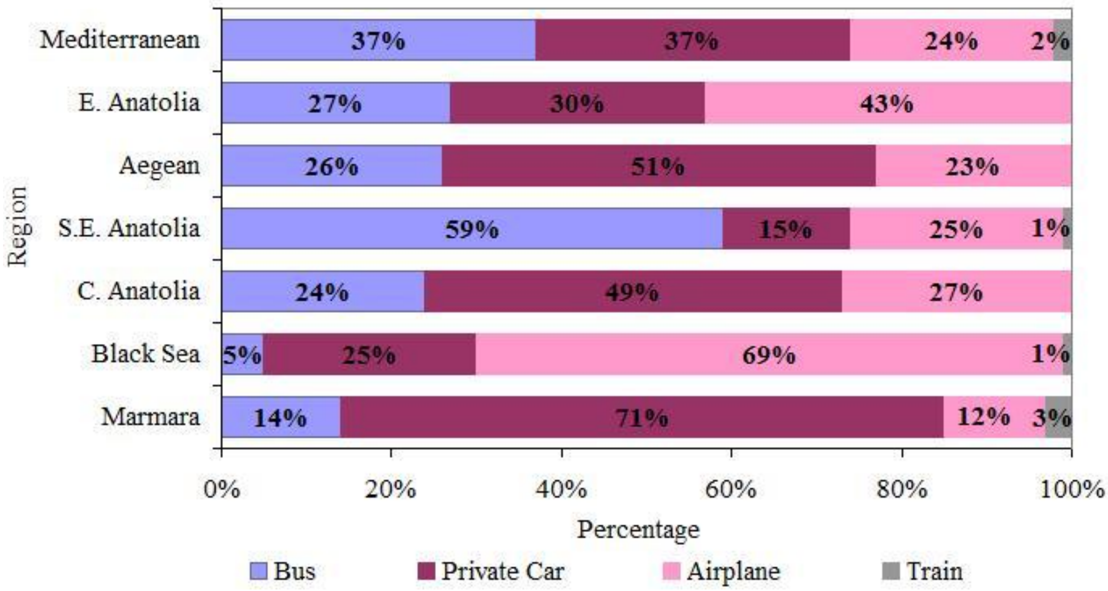

Figure 3.11. Modal split of the CO_2 emissions per capita from intercity transport in Turkey. (Mt-CO_2/capita) [25].

3.3. The Transport Sector in Turkey

From the foundation of the Republic, until the 1950s, due to the implementation of proper national transport policies and the lack of quality road network, rail transport was the leading mode. In 1950, regarding passenger transport, the share of rail, road, maritime and air transport were 49.9, 42.2, 7.5 and 0.6%, respectively. Similarly, regarding freight transport, the shares were realized as 55.1, 27.8, 17.1 and 0%, respectively. Since the early 1950s, however, aided by the funds from the Marshall Plan and the foundation of Directorate General of Highways (in 1950), road network in Turkey was speedily developed and the share of road transport began to increase. As of 2010, the share of road transport is realized as 95% in passenger transport and 90% in freight transport [39].

In EU-27 countries, the share of road transport for inland passenger transport is 92% and it is 76% for inland freight transport (in 2008). Compared to EU-27 countries, in Turkey, the share of road transport in passenger transport is nearly the same, but the difference is about 14% for freight transport [35].

On the other hand, the railway sector has featured a growing trend in both freight and passenger transport within the last ten years. Especially following the construction of the first high-speed rail line from Ankara to Eskisehir, the popularity of rail transport began to increase (This line is part of the Ankara-Istanbul high-speed line which is still under construction). Additionally, in 2011, the second line from Ankara to Konya opened. By the end of 2010, total length of high-speed railway line is 888 kilometers (featuring 12 train sets with a total capacity of 5028 passengers) [40].

In 2010, the maritime transport had a share of 0.37% in passenger transport, and 3% in freight transport [39]. Maritime transport is growing slowly because it can not compete well against road transport due to its cost and speed. But, it has started to receive importance in transport policies and strategies. From 2003 to 2009, the total amount of freight handled increased 62% from 190 to 309 million tons (Mt). Likewise, the total amount of containers handled in the ports increased 76% from 2,492 to 4,404 million Twenty-feet Equivalent Units, (TEU) [41]. It is projected that, by 2023, the share of maritime in freight and passenger transport will reach to 12 and 4%, respectively [39].

Air transport has been one of the fastest growing sectors in the last ten years. Between 2004 and 2010, the total number of domestic passengers increased by 250% (from 14.4 to 50.6 million); international passengers increased by 71% (from 30.5 to 52.2 million) and total number of passengers increased by 129% (from 44.9 to 102.8 million) [42,43].

The evolution of passenger and freight transport in Turkey with respect to transport modes are given in Tables 3.6 and 3.7 (unavailable data are hyphenated). It can be seen that road transport dominates other modes in both freight and passenger transport.

Additionally, three of the main indicators “the total number of vehicles”, “the total number of private cars” and “the motorization rate” (also known as car ownership that means the number of cars owned per 1000 persons) are presented in Figures 3.12 and 3.13.

Table 3.6. Passenger transport by transport modes in Turkey (million passenger-kilometers) [44].

Years	Road	%	Rail	%	Maritime	%	Air	%	Total
1984	87539	95.1	3489	3.8	120	0.13	864	0.9	92012
1989	133833	96.4	3681	2.7	171	0.12	1079	0.8	138764
1994	140743	95.7	3941	2.7	47	0.03	2268	1.5	146999
1999	175236	95.8	4263	2.3	34	0.02	3349	1.8	182882
2004	174312	95.8	3835	2.1	621	0.34	3223	1.8	181991
2009	212464	98.3	3572	1.7	-	-	-	-	216036

Table 3.7. Freight transport by transport modes in Turkey (million ton-kilometers) [44].

Years	Road	%	Rail	%	Maritime	%	Airway	%	Total
1984	43878	74.1	7532	12.7	7719	13.0	63	0.1	59192
1989	68239	82.2	7571	9.1	7152	8.6	95	0.1	83057
1994	95020	91.3	8215	7.9	587	0.6	198	0.2	104020
1999	150974	90.0	8237	4.9	8200	4.9	286	0.2	167697
2004	156853	92.0	9334	5.5	3929	2.3	321	0.2	170437
2009	176455	94.6	10163	5.4	-	-	-	-	186618

In 2010, the total number of motor vehicles has been 15 million and the number of cars about 7.5 million [45]. Moreover, the motorization rate has increased rapidly in the early 1990s and this trend is still continuing. The rate was about 75 in 2004 [46], but in 2010 it reached to 94 cars per 1000 persons [35].

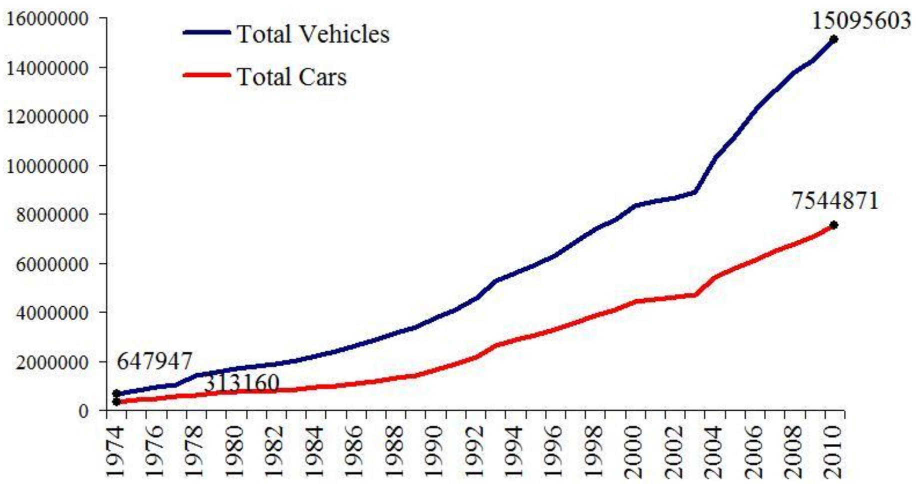

Figure 3.12. Total number of vehicles and private cars in Turkey [45].

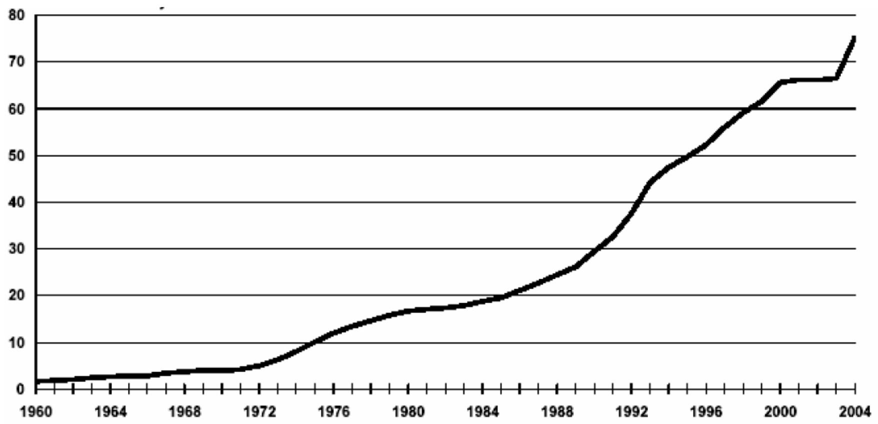

Figure 3.13. Motorization rates in Turkey (cars per 1000 inhabitants) [46].

4. THE MARKAL APPROACH TO ENERGY SYSTEMS MODELING

MARKAL is a dynamic, linear optimization driven mathematical modeling system based on the minimization of the total discounted energy system cost while satisfying various energy supply-demand balance, capacity, quality, input-output relationship and other user defined constraints over a specific planning horizon. A MARKAL approach is usually implemented with respect to a RES [47], which is a simplified demonstration of an energy system network ranging from the extraction of energy sources to the consumption of end-users [48].

As such, various energy, environment and economy related aspects of the real energy system to be investigated can easily be incorporated into the MARKAL model in any desired detail and time horizon, as long as the necessary model parameters can be extracted or estimated with sufficient reliability [17].

As the above description indicates, the MARKAL approach is deemed quite suitable for the primary aim of this study which is (as explained in the introduction section) the general supply-demand balance, CO_2 emissions and policy analysis in the energy sector with special emphasis on the energy balance and CO_2 emissions of the transport sector (by four main modes and 23 sub-modes) in Turkey through the period 2006-2051 with respect to the MARKAL-Turkey model developed in the earlier studies and expanded in this study.

The MARKAL modeling approach was developed in 1970s under the International Energy Agency's (IEA) Energy Technology Systems Analysis Programme (ETSAP) [48]. Being an energy and environmental policy analysis tool, the MARKAL model is consistent with the United Nations Framework Convention on Climate Change (UNFCCC) [49]. MARKAL is a popular modeling tool and has been used by many countries and institutions for energy and environmental policies and research. Since its introduction, the modeling approach has been used by 38 countries and 79 institutions [50], which provides the additional advantage of easy menchmarking of the investigated system’s characteristics, properties and performance with others.

The MARKAL modeling tool can be used for the analysis of either the entire energy system or some specific sectors like transport, industrial and residential etc. The RES covers technological and economical data of the whole systems, but to make an in depth analysis for a specific sector, one can keep the data of other sectors unchanged and revise the data for the target sector.

In a MARKAL model an energy system typically consists of five elements; demands, energy sources, sinks, technologies and commodities. Demands stand for the sectors requesting service from the energy system such as agriculture, residential, industrial and transport sectors. Energy sources represent mining and imports and the sinks represent the exports. Technologies or processes transform an energy input to an output to provide service for the demand sectors. Finally, commodities are the elements produced or consumed during the processes in the entire energy system, such as energy carriers, energy services, materials and emissions [51].

In the RES network sources, sinks, technologies and demands are shown as nodes, whereas commodities except for the emissions are shown as links and finally the emissions are shown by open-ended links [51]. Figure 4.1 shows a simple RES diagram.

There are numerous energy models and they differ from each other in technological details and scope of economical basis. The energy models can be divided into two main categories; top-down and bottom-up models. Top-down models cover the entire economy considering macroeconomic parameters like wages, consumption and interest rates. Bottom-up models are technology explicit models and they firstly focus on the energy sector rather than the entire economy. They can be further divided into two groups; partial equilibrium and simulation models. Partial equilibrium models like MARKAL, optimize the system for the least cost or maximum surplus in the energy sector [51].

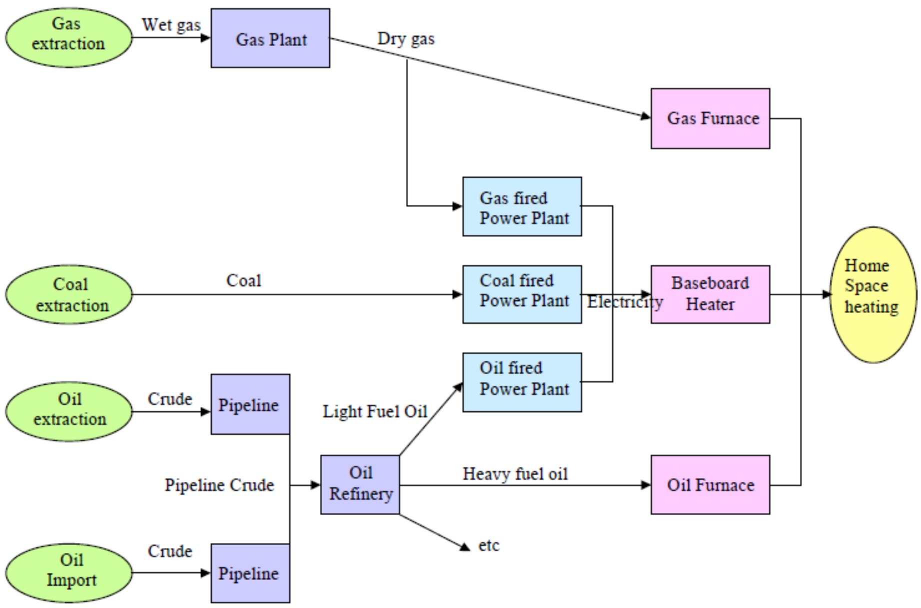

Figure 4.1. Partial view of a simple RES [51].

After these general explanations, in the following sections the mathematical basis of a generic MARKAL model is described by referring at the MARKAL documentation prepared by Loulou *et al*. [51].

4.1. Mathematical Formulations of the MARKAL

Principally, the model minimizes the discounted total energy system cost over a planning horizon by satisfying both the predefined and user-defined constraints like capacity and activity constraints, energy balance constraints, emissions constraints etc.

The mathematical formulations of the model are described in three groups: decision variables, objective function and constraints.

4.1.1. The Decision Variables

The decision variables are the unknown (free) factors whose values are determined by the model as a result of the optimization runs. These variables are;

INV(t,k): New capacity investment for technology *k*, in period *t*. The unit for an investment depends on the sector. For example, for the transport sector, capacity unit is billion-vehicle kilometers. The added investment exists during its lifetime and this lifetime can be a fractional multiple of the length of a period. (The coefficients of these varibles in the objective function are the annualized investment costs which are defined by Equation 4.3)

CAP(t,k): Installed capacity of technology *k*, in period *t*. The units are the same as for the investments. (The coefficients of the varibles in the objective function are the unit fixed operating and maintenance costs which are provided by the user)

ACT(t,k,s): Activity level of technology *k*, in period *t*, during time slice *s*. Petajoule (PJ) is the unit for all energy technologies. This variable is not defined for end-use technologies like vehicles in the transport sector. Because the activity level for the end-use technologies are assumed the same with the available capacity. (The coefficients of the variables in the objective function are the unit variable operating and maintenance costs, which are provided by the user)

MINING(t,c,l): Quantity of extracted commodity *c*, at price level *l*, in period *t*. (The coefficients of these variables in the objective function are the unit costs of extracting related commodities, which are provided by the user)

TRADE(t,c,s,imp (or exp)): Quantity of purchased (imp) or sold (exp) commodity *c*, in period *t* for the time slice *s*. This variable is for the endogenous trade between regions.

IMPORT (t,c,l), EXPORT(t,c,l): Quantity of imported or exported commodity *c*, at price level *l,* in period *t*. The coefficients of these variables in the objective function are the unit cost of importing/exporting related commodities, which are provided by the user.

ENV(t,p): Emission of pollutant *p* in period *t*. The coefficients of these variables in the objective function are the unit taxes on the related emissions which, are provided by the user.

4.1.2. The Objective Function

The Net Present Value (NPV) of the total discounted annual cost is aimed at through Equation 4.1.

$$NPV = \sum_{t=1}^{t=NPER} (1+z)^{NYRS \bullet (1-t)} \bullet ANNCOST(t) \bullet \begin{pmatrix} 1+(1+z)^{-1}+(1+z)^{-2} \\ +\ldots+(1+z)^{1-NYRS} \end{pmatrix} \qquad (4.1)$$

NPV is the net present value of the total cost for all regions over the full planning horizon, NPER is the number of periods in the planning horizon, *z* is the general discount rate, NYRS it the number of years in each period *t*, and ANNCOST(t) is the annual cost for period *t* which is defined as in Equation 4.2.

$$\begin{aligned} &\mathrm{ANNCOST(t)} = \\ &\sum\nolimits_{k} \left\{ \begin{aligned} &\mathrm{Annualized\_Invcost(t,k)} \bullet \mathrm{INV(t,k)} \\ &+\mathrm{Fixom(t,k)} \bullet \mathrm{CAP(t,k)} + \mathrm{Varom(t,k)} \bullet \sum\nolimits_{s} \mathrm{ACT(t,k,s)} \\ &+\sum\nolimits_{c} \left[\mathrm{Delivcost(t,k,c)} \bullet \mathrm{Input(t,k,c)} \bullet \sum\nolimits_{s} \mathrm{ACT(t,k,s)} \right] \end{aligned} \right\} + \\ &\sum\nolimits_{c,s} \left\{ \begin{aligned} &\mathrm{Miningcost(t,c,l)} \bullet \mathrm{MINING(t,c,l)} \\ &+\mathrm{Tradecost(t,c)} \bullet \mathrm{TRADE(t,c,s,i/e)} \\ &+\mathrm{Importprice(t,c,l)} \bullet \mathrm{IMPORT(t,c,l)} \\ &-\mathrm{Exportprice(t,c,l)} \bullet \mathrm{EXPORT(t,c,l)} \end{aligned} \right\} + \\ &\sum\nolimits_{p} \left\{ \mathrm{Tax(t,p)} \bullet \mathrm{ENV(t,p)} \right\} + \sum\nolimits_{d} \left\{ \mathrm{DemandLoss(t,d)} \right\} \end{aligned} \qquad (4.2)$$

Annualized_Invcost is the annualized cost of investments which is defined by Equation 4.3.

$$\mathrm{Annualized\_Invcost} = \mathrm{INVCOST} / \left(\sum_{j=1}^{LIFE} (1+z)^{-j} \right) \qquad (4.3)$$

Fixom(k,t) and Varom(t,k) are unit costs of fixed and operational maintenance of technology *k* in period *t*, Delivcost(t,k,c) is the delivery cost per unit of commodity *c* to technology *k* in period *t*, Input(t,k,c) is the amount of commodity *c* required to operate one unit of technology *k* in period *t*, Miningcost(t,c,l) is the unit mining cost for commodity *c*, at price level *l*, in period *t*, Tradecost(t,c) is the unit transport or transaction cost for commodity *c* exported or imported in period *t*, Importprice(t,c,l) and Exportprice(t,c,l) are the (exogenous) import/export prices of commodity *c* at price level *l*, in period *t*, Tax(t,p) is the tax on emission *p* in period *t*, and DemandLoss(t,d) is the welfare loss incurred by consumers when a service demand *d* in period *t* is less than its value in the reference case.

4.1.3. The Constraints

<u>4.1.3.1. Satisfaction of Demand Equation.</u> For each time period *t*, demand *d*, the total activity of end-use technologies must be at least as the specified demand.

$$\begin{gathered}\text{Sum \{over all end-use technologies k, such that k supplies service d\}} \\ \text{of } CAP(t,k) \geq D(t,d)\end{gathered} \tag{4.4}$$

<u>4.1.3.2. Capacity Transfer Equation.</u> For each technology *k*, period *t*, the available capacity in period *t* is equal to the sum of investments made at past and current periods, and whose physical life has not ended yet, plus capacity in place prior to the modeling horizon and still in place.

$$\begin{gathered}CAP(t,k) = \text{Sum\{over t and all periods t' preceeding t and such that} \\ t\text{-}t' \leq LIFE(k)\} \text{ of } INV(t',k) + RESID(t,k)\end{gathered} \tag{4.5}$$

RESID(t,k) is the capacity of technology *k* due to investments that are made prior to the initial model period and still exist in period *t*.

<u>4.1.3.2. Use of Capacity Equation.</u> For each technology *k*, period *t* and time slice *s*, the activity of the technology may not exceed its available capacity, as specified by a user defined availability factor.

$$ACT(t,k,s) \leq AF(t,k,s) \bullet CAPUNIT \bullet CAP(t,k) \tag{4.6}$$

AF(t,k,s) is the fraction of time that the capacity is available to operate for each technology *k*, period *t* and time slice *s*, and CAPUNIT is the unit conversion factor between units of capacity.

Such constraints are not defined for end-use technologies due to the assumption that activity for end-use technology is always equal to the installed capacity.

<u>4.1.3.3. Energy Balance Equation.</u> For each commodity *c*, time period *t* disposition of each commodity should not exceed its supply.

$$\sum_{c,t}\begin{bmatrix}\sum_k \mathrm{Output}(t,k,c)\bullet \mathrm{ACT}(t,k,s)+\sum_l \mathrm{MINING}(t,c,l)+\\ \sum_l \mathrm{FR}(s)\bullet \mathrm{IMP}(t,c,l)+\mathrm{XCVT}(c,i)\bullet \mathrm{TRADE}(t,c,s,i)\end{bmatrix}\geq \sum_{c,t}\begin{bmatrix}\mathrm{XCVT}(c,0)\bullet \mathrm{TRADE}(t,c,s,e)+\sum_l \mathrm{FR}(s)\bullet \mathrm{EXP}(t,c,l)\\ +\sum_k \mathrm{Input}(t,k,c)\bullet \mathrm{ACT}(t,k,c,s)\end{bmatrix} \tag{4.7}$$

Input (t,k,c)/Output (t,k,c) is the amount of commodity *c* required/produced per unit of technology *k* in period *t*, FR(s) is the fraction of the year covered by time slice *s*, and XCVT(i)/XCVT(o) is the transaction cost for importing/exporting one unit of commodity.

Beside these constraints, Electricity and Peak Reserve Constraints, Optional Emission or Tax Constraints, Electricity Base load Constraints and finally the user defined constraints may be defined.

4.2. The MARKAL-Turkey Model

Being one of the most popular energy modeling approaches, MARKAL has been used in countries such as the United States, the United Kingdom and some EU countries. It was also chosen for Turkey and used as a decision support system for energy and environmental policy making.

With this objective in mind, in this thesis, it is aimed to analyze the overall CO_2 emissions and especially the emissions from the transport sector in Turkey by using a

MARKAL based national level energy model. MARKAL is a dynamic linear optimization modeling system which minimize the total discounted energy system cost over a time horizon in a specific region (or regions) while satisfying the energy supply-demand balance and various pre-defined or user defined constraints. The model is based on a RES, which is a framework of the energy system from the extraction of the energy sources to the consumption of demand sectors.

The model used in this study is set up for the planning horizon 2006-2051 and the analysis is conducted in nine five-year periods. The overall model is actually developed in the earlier studies, while the transport sector is fully overhauled and greatly expanded in this study. The transport sector is analyzed in four main transport modes: road transport, rail transport, maritime transport and air transport. These modes are further detailed into 23 sub-modes and the model data regarding these sub-modes are compiled from various state institutions, private companies, and non-governmental organizations.

The MARKAL-Turkey model is a national level energy model which was built with respect to a RES, a simplified network of the energy system in Turkey. The model is developed for the evaluation and forecast of both the total discounted cost and the overall and sectoral CO_2 emissions of Turkey, while satisfying national energy supply-demand balance, capacity, quality and other user-defined constraints. The model is also intended to guide policymakers in determining the mitigation options for both the short and the long term national energy and environmental policies and investigating the opportunities and threats of these policies on the national energy sector (especially issues regarding the energy supply-demand balance, pricing, investment etc.).

Thus, the energy system (and the resulting CO_2 emissions) in Turkey is aimed to be modeled in detail based on technologies, sectors and production, transfer and consumption processes. Additionally, through the generation and analysis of alternative scenarios, it is aimed that the model would support strategic decision making and international negotiating power by enabling the studies on the effects of energy and environmental policies on the national economy and local and global environment.

The MARKAL-Turkey model consists of six main parts, namely, Primary Energy Sources, Conversion Technologies, Energy Carriers, Production Technologies, End-Use Technologies and Demand Sectors.

The primary energy sources are the origins of the energy system which supply the processes by the conversion technologies like refineries and power plants. The energy produced by the conversion processes are transferred by energy carriers to production technologies and to end-use technologies such as, space heating, road motor vehicles, and office appliances. Finally, all the production and end-use technologies are grouped under five demand sectors, namely agricultural, industrial, residential, services and transport sector. Figure 4.2 presents the simplified RES of the MARKAL-Turkey model.

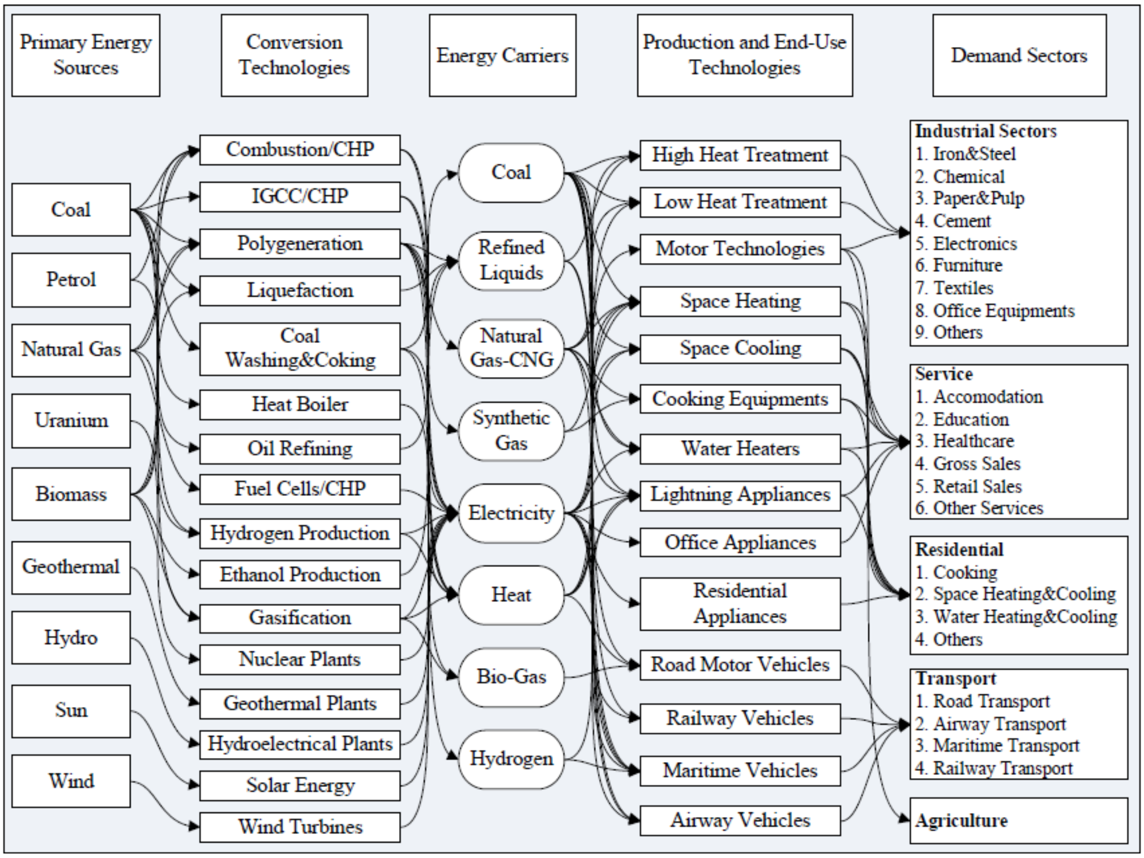

Figure 4.2. Simplified reference energy system for MARKAL-Turkey model.

5. METHODOLOGY AND ASSUMPTIONS

Transport sector energy modeling studies heavily depend on social and economic factors such as, vehicle usage and types, motorization rate, GDP, education and driving characteristics. Since all of these parameters require much effort to be analyzed in detail, incorporating these factors into energy models are difficult [21].

The TUIK is the responsible authority to collect data from institutions and publish them as the official statistics for Turkey. But, although the transport sector plays an important role on the economic and social growth of Turkey, limited statistics exist regarding this sector.

Thus, for the current study first available relevant data are collected and then for the missing specific and key data, related State and Government agencies, Non-Governmental Organizations (NGOs) and private organizations are contacted; these include the Ministry of Transport (MoT), Ministry of Internal Affairs, Ministry of Energy and Natural Resources (MENR), Ministry of Environment and Forestry and their affiliated institutions and also some municipalities and NGOs. Based on all collected data, a series of assumptions are made to provide the relevant data required by the model.

In the study, the MARKAL-Turkey model is used as basis with the existing data left unchanged for other sectors. However, regarding the transport sector, whose detailed analysis and evaluation is the primary aim, existing modes are further detailed and new modes and sub-modes are added to the model. The base year for the model is still taken as 2006 and the time horizon being 2006-2051.

For a detailed analysis the transport sector is divided into four main transport modes; road transport, rail transport, maritime transport and air transport. These modes are further detailed into sub-modes. The structure of all this classification is shown in Figure 5.1.

For each mode and sub-mode the basic data that the MARKAL model requires are; total kilometers to be traveled, fuel efficiencies, purchase prices and annual fixed operating and maintenance costs. The reference data are compiled for the year 2006 and the data for the years between 2011 and 2051 are estimated based on statistics and the existing data in the MARKAL-Turkey model.

The target demand data for the model is the total vehicle kilometers traveled, that stand for the total distance driven by a specific sub-mode regardless of the number of passengers or amount of freight carried. But, in some transport modes, other key statistics, namely ton-kilometer (or ton-mile) and passenger-kilometer are used. Ton-kilometer is calculated by the multiplication of the freight amount (in tons) and the distance traveled (in kilometers or miles). Likewise, passenger-kilometer is calculated by the multiplication of the number of passengers with the distance traveled. These statistics are especially important in assessing the impacts of policies aiming transport mode changes and are considered in the related scenario analysis discussed in Chapter 6.

In the following section, the methods and assumptions made in the analyses are described by each mode and sub-mode.

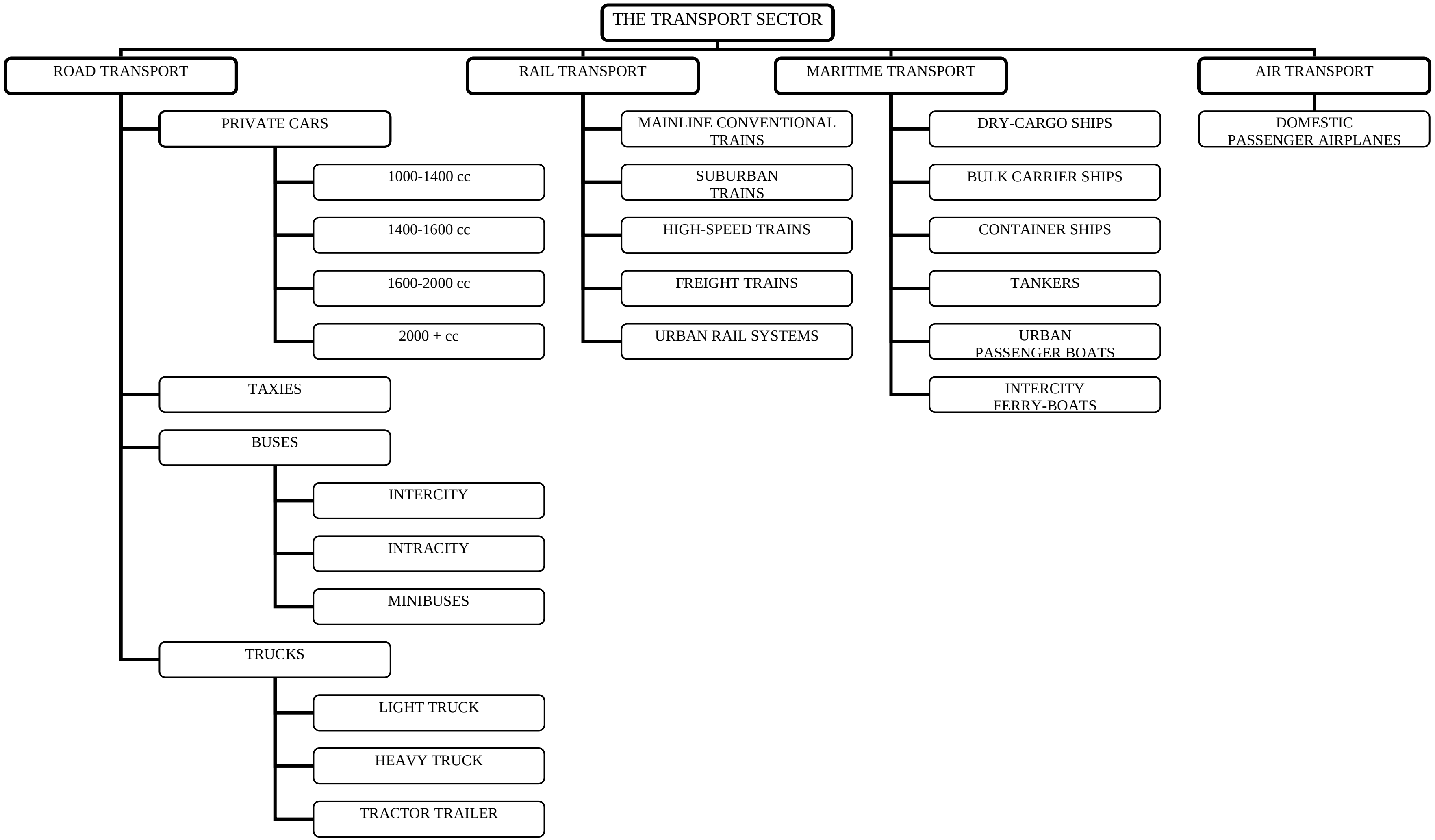

Figure 5.1. The modes and sub-modes of the transport sector considered in this study.

5.1. The Road Transport

Road transport is analyzed in four parts; private cars, taxies, buses and trucks.

5.1.1. Private Cars

Being a key transport mode in Turkey, private cars are divided into four sub-modes according to their motor cylinder volumes, 1000-1400, 1400-1600, 1600-2000, and 2000+ cubic centimeters (cc). The estimate for the total vehicle kilometers traveled by private cars is calculated by summing up both the estimates for intercity and urban travel.

The intercity travel data are obtained from the Traffic and Transportation Survey of the General Directorate of Highways (KGM) [52]. These data indicate that in 2006 a total of 43188 million kilometers were traveled by private cars.

For urban travel, no data are published neither by the Ministry of Transport nor the TUIK. Next, metropolitan municipalities of major cities were approached for those data. However, only İstanbul Metropolitan Municipality (IBB) could provide the relevant data.

So the total urban travel amount is estimated by taking the IBB data as reference. It is assumed that the total private car kilometer in a city is proportional to the number of cars and to the size of the urban area (in square-kilometers) of that city. The car stock data are taken from the Road Motor Vehicle Statistics [53] published by the TUIK and the sizes of the urban areas are calculated through the Google Earth-Pro Software.

For ease of computation, the urban areas considered are restricted to towns with more than 100000 population. The total vehicle kilometers traveled by the private cars for each city is estimated by this method. Then, summing all these values, the total private car vehicle kilometers in Turkey is reached. The resulting value is 25573 million vehicle kilometers of urban private car travel, which (when summed up with the intercity value) leads to 68761 million vehicle kilometers for all private car travel (for the base year of 2006).

In distributing the overall private car travel demand into the sub-modes, it is assumed that each type of car is used with the same frequency (annual kilometer) regardless of its cylinder size. Thus, the distribution is made regarding the number of cars in each sub-mode, namely 1000-1400, 1400-1600, 1600-2000 and 2000+ cc. The relevant data are retrieved from the General Directorate of Security (EGM). The distributed total private car travel demand for each sub-group is summarized in Table 5.1. The data also show that percentage of the cars in each sub-group are 38, 50, 10 and 2, respectively.

Table 5.1. Annual mileage data for the private car sub-modes in 2006.

Mode	Sub-Mode (cc)	Number of Cars	%	Annual Mileage (million kilometers)
Private Cars	1000 – 1400	2354994	38	26129
	1400 – 1600	3048555	50	34380
	1600 – 2000	588004	10	6876
	2000 +	149438	2	1375
	Total	6140992	100	68761

Next, the automotive companies are consulted, in order to obtain the fuel efficiency factors of the private car sub-mode (for each sub-mode, the fuel consumption data obtained from different makers are averaged out). Likewise, the purchase prices are also obtained from the auto companies and for each sub-mode the average prices are taken as input.

Finally, annual operating and maintenance costs are determined by consulting to experts in the transport sector.

5.1.2. Taxies

Taxies are quite common in big cities and should be analyzed due to their significant share in urban travel. For the three major cities, Istanbul, Ankara and Izmir, data on the number and estimated average daily travel mileage of taxies are obtained from the municipalities.

It is seen that, the total number of the taxies in these major cities is nearly equal to 30% of the total number of commercial cars (which is published in the Road Motor Vehicle Statistics [53] published by the TUIK and covers all commercially registered vehicles in Turkey). Regarding that 30% ratio, it is assumed that the total number of taxies in the rest of the cities is also equal to 30% of the total number of commercial cars in Turkey. It is further assumed that in all cities, (except for Istanbul, Ankara and Izmir in which each taxi travels about 200 kilometers per day), a taxi travels about 100 kilometers per day. With these assumptions; it is estimated that the number of taxies is 43486 and the total distance traveled by taxies is 2536 million kilometers.

The fuel efficiencies, purchase prices and annual operating and maintenance costs of taxies are assumed to be the same as the related parameters of 1400-1600 cc sub-mode of the private cars.

5.1.3. Buses

This mode is analyzed in three sub-modes, namely intercity buses, intracity buses and minibuses.

Intercity buses (or coaches) are the ones that belong to private bus companies and operate between cities for passenger transport. An intercity bus has a capacity of 35-50 passengers.

In order to estimate the total travel demand of intercity buses, the statistics provided by the KGM [52] are referred. In 2006, total kilometers traveled by intercity buses are about 2191 million kilometers. Since, there are no data regarding the number of intercity passenger buses, it is assumed that an average bus travels 400000 kilometers per year and the number of corresponding intercity buses is found as 5478 (by dividing the total annual kilometers with 400000). The assumption of 400000 kilometers is based on expert interviews and is made in order to make the necessary calculations required by the model.

Intracity buses are the ones that operate within the cities mainly for public transport purposes and having 60-100 passenger capacities. Actually, there are two types of intracity buses: the ones that belong to the municipalities and the ones that are privately owned.

The municipalities are the main transport authorities in the cities, but, they do not keep nor publish specific transport statistics. Therefore, the municipalities of the three major cities, Istanbul, Ankara and Izmir are contacted and relevant data regarding the number of buses and the total annual kilometers traveled by these buses are obtained for the base year 2006. These values are presented in Table 5.2.

Table 5.2. The number of intracity buses in 2006 by major cities.

	MunicipalityBuses	PrivateBuses	Total
İstanbul	2076	2038	4114
Ankara	1261	199	1460
İzmir	1518	-	1518
Total	4855	2237	7092

No data were available on the total number of intracity buses. But, the TUIK annually publishes the number of buses for each city in three groups; commercial, public and private. When these data are analyzed, it is seen that the realized sum of intracity buses in Istanbul, Ankara and Izmir, is nearly equal to the total number of “official buses” (the number of buses registered as “state owned”) in these three cities, which are 4855 and 4902, respectively [53].

Therefore, it is assumed that the number of official buses in Turkey, which is 15427 [53], is equal to the total number of intracity buses. In fact, when the privately owned buses are considered, a total of 7000 is reached in these three cities. But, this surplus is considered as reserve for potential shortcomings in the estimations due to the possibility that some official buses may not be used for public transport purposes (Official buses cover all the state owned buses, not only the ones owned by municipalities but also the ones owned by various institutions such as the military etc. Thus, it is assumed that the surplus from private buses balances the quantity that does not serve the purpose of this study). As indicated by the IBB, each intracity bus in İstanbul makes 85000 kilometers per year; but in Izmir and Ankara such buses travel about 60000 kilometers per year. The reference annual mileage is taken as 60000 for the remaining cities. The total number of buses is multiplied by the average annual mileage values for each city in order to estimate the total intracity bus vehicle kilometer value.

Table 5.3. The total number of buses in Turkey in 2006 [53].

	Private	Commercial	Official	Total
İstanbul	7572	36788	1947	46307
Ankara	3756	8491	1898	14145
İzmir	3117	10426	1057	14600
Sub-Total	14445	55705	4902	75052
Country Total	31043	129479	15427	175949

Minibuses are privately owned small sized buses which operate within the cities like intracity buses. A typical minibus has a capacity of 10-25 passengers.

Like the intracity buses, no data were available regarding neither the number of minibuses in Turkey nor their annual mileage, other than the data provided by the three major cities for the year 2009 (on average a minibus travels 65000 kilometers per year). So, the value of 65000 kilometers per minibus is generalized over the country.

Additionally, the TUIK publishes number of minibuses in three groups; private, commercial and official minibuses. The commercial minibuses include those used in public transport, but this sub-class also covers all other types of commercially registered minibuses. The data from TUIK [53] and the data from the three cities are compared for the year 2009 and it is seen that the minibuses used in public transport account for the 35% of the total commercial minibuses in these three cities. Thus, this estimated percentage is also used for the year 2006. Although, it is probable that the percentage is higher than 35 in cities other than the three major ones, due to the prevalence of minibuses in public transport, 35% is used for the remaining cities (which means that the total number of minibuses used for public transport in these cities is equal to the 35% of the total number of commercial minibuses published by the TUIK [53]).

Thus, it is concluded that, in 2006, the total number of minibuses used for public transport is 50533 and the total kilometers traveled by them are about 3284 million kilometers. Table 5.4 summarizes the data for these three bus sub-modes.

Table 5.4. Annual mileage data for the bus sub-modes for 2006.

Mode	Sub-Mode	Average Annual Mileage (kilometers)	Total Annual Mileage (million kilometers)
Buses	Intercity	400000	2191
	Intracity	75473	1164
	Minibus	65000	3284

To obtain the fuel efficiency factors of bus sub-modes municipalities, experts in transport sector and the data presented in the web-sites of the automotive companies are consulted. Likewise, the purchase prices are taken from these websites and the average prices are taken as reference.

Finally, the annual operating and maintenance costs are determined by consulting to the experts in the sector.

5.1.4. Trucks

This mode consists of three sub-modes; light trucks, heavy trucks and tractor trailers. All these vehicles are used in freight transport and they operate mostly between cities. The TUIK annually publishes the number of trucks and light trucks. But, the annual kilometers data taken from the KGM [52] cover only the intercity traffic and excludes intracity traffic. So, the truck travel demand data does not cover all trucks. To overcome this problem, an average annual travel mileage for each sub-mode is estimated to find the number of trucks that travel between cities. In brief, total vehicle kilometer data are obtained from the KGM, while the average travel distance by the vehicles is estimated.

Light trucks are the vehicles that can carry up to 10-15 tons. According to the KGM [52], in 2006, total distance travelled by the light trucks was 3993 million kilometers. With the assumption that each light truck travels about 40000 kilometers per year, the total number of light trucks those travel between cities is estimated as 99825 (by dividing 3993 million kilometers to 40000 kilometers).

Heavy trucks are the vehicles that can carry up to 20-25 tons. In 2006, total distance travelled by the heavy trucks was 12385 million kilometers [52]. With the assumption that each heavy truck travels about 100000 kilometers per year, the total number of heavy trucks those travel between cities is estimated as 123850.

Tractor trailers are the vehicles with a tractor unit pulling trailer(s) and can carry up to 30-40 tons. In 2006, total distance travelled by the trailers was 2821 million kilometers [52]. With the assumption that each tractor trailer travels about 100000 kilometers per year, the total number of tractor trailers is estimated as 28210.

Table 5.5. Annual mileage data for the three truck sub-modes for 2006 [52].

Mode	Sub-Mode	Average Annual Mileage (kilometers)	Total Annual Mileage (million kilometers)
Trucks	Light Truck	40000	3993
	Heavy Truck	100000	12385
	Tractor Trailer	100000	2821

In fact, since the travel demand data is directly taken from the KGM, the annual mileage for each vehicle is not necessary for the model. But, in order to calculate the investment cost and fixed operating and maintenance cost, it is necessary to convert units from Turkish Lira/unit to Pound/PJ/year. Therefore, the average annual distance traveled (and the average annual energy consumption in PJ) by each sub-mode is required in order to make the necessary unit conversions.

Besides, the experts in the transport sector and the data presented in the web-sites of the automotive companies are referred in order to find the fuel efficiency factors, purchase prices and annual operating and maintenance costs for the trucks.

5.2. Rail Transport

Rail transport is evaluated for three main categories, namely passenger trains, freight trains and urban rail systems. Passenger trains are further detailed in three sub-modes, namely conventional intercity trains, suburban trains and high-speed intercity trains. Additionally, with freight trains and urban rail systems, the rail transport is divided into five sub-modes.

The Turkish State Railways (TCDD) is the only authority for the operating rights of all railways in Turkey. Thus, all statistics regarding the railways are prepared and published by the TCDD. In this study, the Turkish Railways Annual Statistics Book [44] published by the TCDD is referred. The number of trains, total passenger-kilometer, train-kilometer and ton-kilometer data are available in this reference book with respect to train types.

5.2.1. Passenger and Freight Trains

According to the TCDD [44], in 2006, the total train kilometers traveled by the conventional, suburban, high-speed and freight trains are about 20.8, 4.6, 0, and 17.7 million kilometers, respectively.

Since the first high-speed train line, from Ankara to Istanbul, was still under construction in 2006, the total kilometer value for that mode is 0. But the first section of that line, from Ankara to Eskisehir, was opened in 2009. Thus, beginning with the year 2009, high-speed trains are considered in this study. Each high-speed train consists of 6 wagons and can carry up to 400 passengers.

Conventional mainline trains are used in passenger transport between cities. On average, they consist of a loco and six wagons with a capacity of 400 passengers.

Suburban trains are only used in some cities like Istanbul, Ankara and Izmir. They are used in public transport to connect the suburbs to the city centers. They carry up to 150-200 passengers in a wagon. The number of wagons depends on the line but it can be taken as 4-5 wagons on average.

Freight trains are operated on mainlines and used in freight transport. These trains consist of a diesel or electric loco and rolling stocks (carriages). The number of carriages depends on the distance and the route, but, in this study, it is assumed that a freight train consists of 20-25 carriages with a total capacity of 1000 tons.

For the fuel efficiency factors, purchase prices and annual operating and maintenance costs the TCDD [44] and sector experts are consulted.

5.2.2. Urban Rail Systems

Since the number of cities that have urban rail systems is increasing, this sub-mode is added to the study. In Turkey, there are 11 cities having a public rail system; Istanbul, Ankara, Izmir, Adana, Bursa, Antalya, Eskisehir, Konya, Samsun, Kayseri and Gaziantep. Some of these cities have metro systems, some have light rail systems and some have tram systems. In this study, it is assumed that all concerned cities have a light rail systems consisting of units having four wagons with a capacity of 600 passengers.

To estimate the total kilometers travelled by all city rail systems, the above mentioned municipalities are consulted and with the obtained data, a total of 10 million kilometers is reached for the year 2006.

The fuel/energy efficiencies, purchase prices and annual operating and maintenance costs are obtained from the mentioned municipalities and the feasibility studies of some recent rail system projects in Turkey.

5.3. Maritime Transport

In this study, regarding maritime transport, just domestic operations are considered under six sub-modes, which are dry cargo ships, bulk carriers, container ships, tankers, urban passenger boats and intercity ferry-boats.

The main responsible authority for maritime transport is the Undersecretariat for Maritime Affairs, and therefore, most of the data are compiled by this organization. The maritime statistics include ton-kilometer and handling data, but, the annual mileage data for individual or sets of vessels are not available. Thus, to find the necessary mileage data, ton-kilometer is used together with some assumptions, which are explained in section 5.3.1.

5.3.1. Cargo Ships

Cargo ships are evaluated in four sub-modes, namely dry cargo ships, bulk carriers, container ships and tankers. As stated above, the mileage data are not available for the maritime transport. Thus, some assumptions are made to estimate the input data required for the MARKAL model.

First, it is assumed that the ships with a capacity larger than 10000 Gross-Tons (GT) are not used in domestic lines. Then, within this upper bound, the number of ships, total GT and total Dead Weight Tons (DWT) values are obtained for each sub-mode (dry cargo ships, bulk carriers, container ships and tankers). By these data, the total and average GT and DWT values are estimated for each sub-mode. The estimated average GT values for the mentioned sub-modes are 1500, 3500, 5000 and 1500 GT, and the average DWT values are 2300, 5000, 6500 and 1800 DWT, respectively. Finally, with the estimated DWT and number of ships, it is possible to distribute the total ton-kilometer value to each sub-mode and estimate the annual kilometer values for each sub-mode. The related calculations and values are presented in Table 5.7. Fuel efficiencies, purchase prices and annual operating costs are taken from a maritime agency that operates in the maritime transport sector.

Table 5.6. Average GT and DWT values for cargo ship sub-modes (<10000 GT).

Ship Type	Number of Ships	%	Total GT	Total DWT	Average GT	Average DWT
Dry Cargo	567	60.4	887002	1399578	1500	2300
Bulk Carrier	21	2.2	70858	112955	3500	5000
Container	45	4.8	231266	301113	5000	6500
Tanker	305	32.6	438000	635623	1500	1800
Total	938	100.0	1627143	2449269		

Table 5.7. Freight and mileage data for cargo ship sub-modes.

Ship Type	Freight (Tons)	Freight (1000 Ton-Miles)	Average DWT	Ship-Miles	Ship-Kilometers
Dry Cargo	9608737	2276029	2300	989578	1832698
Bulk Carrier	355879	84297	5000	16859	31224
Container	22146	7535	6500	13729	25426
Tanker	5168721	1224319	1800	680177	1259688
Total	15155483	3592180		1700343	3149036

5.3.2. Ferry Boats and Passenger Boats

Ferry boats carry both passenger and motor vehicles within/between the cities, whereas passenger boats carry only passengers within a city or between cities.

Ferries and passenger boats are used in Istanbul, Izmir and Canakkale. Relevant data could only be obtained from Istanbul and Izmir. Therefore, city of Canakkale, whose ferry/passenger boat activity is negligible anyway, is excluded in this study. According to the data obtained from Istanbul and Izmir, the total kilometers traveled by ferry boats and passenger boats are 1.1 and 3.7 million kilometers, respectively.

The fuel/energy efficiencies, purchase prices and annual operating and maintenance costs are taken from the municipalities and the feasibility studies of some recent maritime transport projects in Turkey.

5.4. Air Transport

In this study, the air transport is considered just for domestic flights, (international flights being excluded). But, finding the total kilometers in the airway sector turned out to be a difficult issue. Most of the airway companies do not publish annual operational statistics except the Turkish Airlines (THY) which is the biggest company in the sector. As shown in Figure 5.2 operational data for 2006 are obtained from THY Annual Report 2006 [54].

For the remaining data, each airway company is contacted and data for 2006 are obtained from some of these companies. It is seen that the obtained data cover 92% of the total domestic passengers in 2006. The data are then extrapolated to cover 100% of the total.

Table 5.8. Domestic travel data of THY [54].

	2002	2003	2004	2005	2006
Number of Landings	51542	49959	51557	65448	78910
Km Flown (Thousand)	28782	28087	28734	36049	45282
Available Seat-Km (Million)	3858	3863	4253	5457	7123
Revenue Passenger-Km (Million)	2732	2790	3236	4016	5213
Passenger Load Factor (%)	70.8	72.2	76.1	73.6	73.2
Available Ton-Km (Million)	468	478	515	647	806
Revenue Ton-Km (Million)	278	283	325	394	504
Overall Load Factor (%)	59.4	59.2	63.1	60.9	62.5
Revenue Passengers (Thousand)	4970	5031	5850	7197	8906
Cargo (Tons)	26346	26628	28800	29233	32085
Mail (Tons)	1759	1289	1323	1088	1295
Excess Baggage (Tons)	896	1077	999	1490	1460

The estimated total domestic flight kilometers between 2006 and 2009 are presented in Table 5.8. It can be seen that in three years time, total flights increased by 35%, which accounts for an average annual growth of 10.4%.

Table 5.9. Estimated travel and passenger data for domestic flights in Turkey.

Year	Number of Passengers	Annual Travel (kilometers)
2006	14399939	74587926
2007	15985437	82319397
2008	17916388	89393920
2009	20613480	100607919

The fuel/energy efficiencies, purchase prices and annual operating and maintenance costs are taken from the companies that shared their operational data and the websites of aircraft manufacturers.

6. SCENARIOS AND RESULTS

In this section all the scenarios are defined and their results are presented.

6.1. Definition of the Scenarios

As mentioned in previous chapters, the MARKAL model minimizes the total energy system cost which is comprised of many investment cost, operating cost and other cost components over all considered sectors. While minimizing the total system cost, the model satisfies various constraints such as capacity, activity and demand constraints. Since all sectors are interconnected by the RES framework, the calculated values are the global optimum values but the model also provides optimum results in sectoral level.

In this study, although the model runs cover all sectors and sub-sectors, the primary variations (from the BAU scenario) in the scenarios developed and investigated are all in the transport sector. There are two reasons for this approach; firstly, that this study aims specifically at evaluating the impacts of the CO_2 emissions from the transport sector and secondly, that only the transport sector data are enriched and the model data for the other sectors are kept as they exist in the original MARKAL-Turkey model. Thus, evaluating the results for the transport sector only is deemed to be more useful.

For alternative scenario comparisons and analysis, the base scenario, which assumes that the transport sector will evolve with the current trends, is deployed. Then, taking the base scenario as reference, the alternative scenarios are created to study and better understand the factors affecting CO_2 emissions, energy consumptions and technology preferences. These alternative scenarios feature CO_2 emission bounds, modal shifts in passenger and freight transport and finally fuel price changes and efficiency improvements in automotive technologies.

In all, 26 alternative scenarios are created for the transport sector. These scenarios are created by the ternary combinations of the cases that are shown in Table 6.1 and they are listed with their scenario ID numbers in Table 6.2. The scenario numbers are given based on the order of case settings. For example, the base scenario is listed as 1.1.1 because it comprises the first setting of each case. Likewise, the scenario that consists of 20% modal shifts with no emissions and no efficiency improvement and fuel price change is listed as 1.3.1.

Table 6.1. Cases used in scenario creation.

Case	% Change		
CO_2 Emission Reduction	0%	15%	30%
Modal Shifts in Passenger and Freight Transport	0%	10%	20%
Increase in Auto Fuel Efficiency + Fuel Prices	0%	15%+20%	30%+40%

Table 6.2. Scenarios and their descriptions.

No	Scenario Description
1.1.1	Base Scenario
2.1.1	15% emission reduction, No modal shift, No efficiency improvement and fuel price increase.
3.1.1	30% emission reduction, No modal shift, No efficiency improvement and fuel price increase.
1.2.1	No emission reduction, 10% modal shift, No efficiency improvement and fuel price increase.
1.3.1	No emission reduction, 20% modal shift, No efficiency improvement and fuel price increase.
1.1.2	No emission reduction, No modal shift, 15% efficiency improvement-20% fuel price increase.
1.1.3	No emission reduction, No modal shift, 30% efficiency improvement-40% fuel price increase.
1.2.2	No emission reduction, 10% modal shift, 15% efficiency improvement-20% fuel price increase.
1.2.3	No emission reduction, 10% modal shift, 30% efficiency improvement-40% fuel price increase.
1.3.2	No emission reduction, 20% modal shift, 15% efficiency improvement-20% fuel price increase.
1.3.3	No emission reduction, 20% modal shift, 30% efficiency improvement-40% fuel price increase.
2.1.2	15% emission reduction, No modal shift, 15% efficiency improvement-20% fuel price increase.
2.1.3	15% emission reduction, No modal shift, 30% efficiency improvement-40% fuel price increase.
3.1.2	30% emission reduction, No modal shift, 15% efficiency improvement-20% fuel price increase.
3.1.3	30% emission reduction, No modal shift, 30% efficiency improvement-40% fuel price increase.
2.2.1	15% emission reduction, 10% modal shift, No efficiency improvement-No fuel price increase.
2.3.1	15% emission reduction, 20% modal shift, No efficiency improvement-No fuel price increase.
3.2.1	30% emission reduction, 10% modal shift, No efficiency improvement-No fuel price increase.
3.3.1	30% emission reduction, 20% modal shift, No efficiency improvement-No fuel price increase.
2.2.2	15% emission reduction, 10% modal shift, 15% efficiency improvement-20% fuel price increase.
2.2.3	15% emission reduction, 10% modal shift, 30% efficiency improvement-40% fuel price increase.
2.3.2	15% emission reduction, 20% modal shift, 15% efficiency improvement-20% fuel price increase.
2.3.3	15% emission reduction, 20% modal shift, 30% efficiency improvement-40% fuel price increase.
3.2.2	30% emission reduction, 10% modal shift, 15% efficiency improvement-20% fuel price increase.
3.2.3	30% emission reduction, 10% modal shift, 30% efficiency improvement-40% fuel price increase.
3.3.2	30% emission reduction, 20% modal shift, 15% efficiency improvement-20% fuel price increase.
3.3.3	30% emission reduction, 20% modal shift, 30% efficiency improvement-40% fuel price increase.

In the following sections, the assumptions and the data used in the scenarios are explained and then the results obtained from the model runs, such as CO_2 emissions and total energy consumptions, are presented. Alternative scenarios are evaluated in three groups depending on the number of factor changes from the base scenario. These groups are: the unary case scenarios which feature a single factor change (either emission reduction or modal shift or efficiency and fuel price change), the binary case scenarios which feature two factor changes and the ternary case scenarios which feature triple factor changes.

For example, scenario 2.2.1 is a binary case scenario, because it features 15% reduction in CO_2 emissions and 10% modal shift. Likewise, scenario 2.2.2 is a ternary case scenario, because it features 15% reduction in CO_2 emissions, 10% modal shift and 15% auto efficiency improvement together with 20% fuel price increase.

6.2. The Base Scenario (1.1.1)

In the base scenario the reference year is set to 2006 and it is assumed that the current trends will continue until 2051. The vehicle kilometers (which form the basis of the transport sector energy demand) for the year 2006 are estimated with the methodology described in Chapter 5. The demand values for the future periods are projected through growth rates for each mode and sub-mode, which are estimated by considering the realized vehicle kilometer values up to the year 2010, national policies and sectoral strategies and finally the opinions obtained from the transport sector experts. The demand data for the period 2006-2051 are shown in Table 6.3 (in billion vehicle kilometers for each vehicle type). In addition, demand (vehicle kilometer) constraints are added to the model especially for the calibration of diesel consumptions in 2006 and 2011, and they are relaxed gradually until the year 2051. These constraints are presented in Table 6.4. Finally, the abbreviations used for the sub-modes are given with their definitions in Table 6.5.

Table 6.3. Demand values for the sub-modes in the base scenario (billion kilometers).

Sub-Mode	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
TA	0.075	0.120	0.193	0.284	0.418	0.614	0.821	1.099	1.471	1.968
TB1	2.191	2.479	2.737	2.948	3.176	3.422	3.686	3.971	4.278	4.609
TB2	1.164	1.383	1.642	1.951	2.317	2.752	3.268	3.881	4.610	5.475
TB3	3.285	3.901	4.633	5.503	6.536	7.762	9.219	10.950	13.005	15.446
TC1	26.129	34.150	42.557	50.545	60.031	71.298	84.680	100.573	119.449	141.868
TC2	34.381	44.934	55.996	66.506	78.988	93.813	111.421	132.333	157.170	186.669
TC3	6.876	8.987	11.199	13.301	15.798	18.763	22.284	26.467	31.434	37.334
TC4	1.375	1.797	2.240	2.660	3.160	3.753	4.457	5.293	6.287	7.467
TCX	2.536	3.012	3.578	4.249	5.047	5.994	7.119	8.455	10.042	11.926
TH1	12.385	13.017	13.082	13.148	13.213	13.280	13.346	13.413	13.480	13.548
TH2	2.821	7.020	7.055	11.362	18.298	23.354	29.806	38.040	48.550	61.964
TIDOF	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002
TIDOP	0.004	0.004	0.005	0.006	0.007	0.009	0.011	0.013	0.015	0.018
TL	3.993	4.197	4.411	4.636	4.872	5.121	5.382	5.656	5.945	6.248
TRF	0.018	0.020	0.022	0.024	0.026	0.029	0.032	0.035	0.039	0.043
TRH	0.000	0.003	0.005	0.010	0.016	0.026	0.042	0.054	0.069	0.088
TRM	0.021	0.021	0.021	0.021	0.021	0.021	0.022	0.022	0.022	0.022
TRMET	0.010	0.018	0.025	0.030	0.035	0.040	0.045	0.050	0.060	0.070
TRS	0.005	0.005	0.006	0.006	0.007	0.008	0.008	0.009	0.010	0.011
TSDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
TSKT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
TSKY	0.002	0.003	0.005	0.008	0.011	0.017	0.024	0.032	0.043	0.058
TSTK	0.001	0.002	0.003	0.005	0.008	0.011	0.017	0.022	0.030	0.040

Table 6.4. Constraints bounding shifts among fuel types (%).

Sub-Mode	Fuel	Bound	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
TB1	Diesel	Lower	100	100	95	80	65	50	35	20	10	5
TB2	Diesel	Lower	100	90	75	60	45	30	15	10	5	0
	CNG	Lower	0	10	15	15	10	10	10	5	5	0
C1-C4	Gasoline	Lower	64	40								
		Upper	64	40	40	40	37	37	34	34	30	30
	Diesel	Lower	10	20	20	15	15	10	10	10	5	5
	LPG	Lower	26	40	35	30	25	20	20	15	10	10
TCX	Diesel	Lower	2	2	1.5	1	1	0.5	0.5	0	0	0
	LPG	Lower	98	98	95	80	60	40	20	10	0	0
TH1	Diesel	Lower	100	100	85	70	60	50	40	30	20	10
TH2	Diesel	Lower	100	100	85	70	60	50	40	30	20	10
TL	Diesel	Lower	100	100	85	70	60	50	40	30	20	10
TRF	Diesel	Lower	90	90	85	75	65	55	45	30	30	30
TRF	Electric	Lower	10	10	8	8	6	6	5	5	5	5
TRM	Diesel	Lower	67	67	60	55	50	45	40	30	30	30
TRM	Electric	Lower	33	33	30	25	20	15	15	10	10	10

Table 6.5. Abbreviatons used for the sub-modes.

Sub-Mode	Definiton
TA	Domestic Passenger Airplanes
TB1	Intercity Buses
TB2	Intracity Buses
TB3	Minibuses
TC1	Private Cars (1000-1400 cc)
TC2	Private Cars (1400-1600 cc)
TC3	Private Cars (1600-2000 cc)
TC4	Private Cars (2000+ cc)
TCX	Taxies
TH1	Heavy Trucks
TH2	Tractor Trailers
TL	Light Trucks
TIDOF	Intercity Ferry Boats
TIDOP	Urban Passenger Boats
TRF	Freight Trains
TRH	High-Speed Passenger Trains
TRM	Mainline Passenger Trains
TRMET	Urban Rail Systems (Metro)
TRS	Suburban Trains
TSDY	Bulk-Carrier Ships
TSKT	Container Ships
TSKY	Dry-Cargo Ships
TSTK	Tankers

The results of the base scenario for the transport sector are presented in Table 6.7-12. In the tables “L. Hydrogen” stands for liquefied hydrogen, whereas “G. Hydrogen” stands for gaseous hydrogen. Besides, modal energy consumptions by fuel types (which feature the energy consumptions (in PJ) for each vehicle (TC1, TC2 etc.) by fuel types (diesel, gasoline etc.) throughout the planning horizon) are presented for all scenarios in Appendix A. It should be noted that bio-diesel and ethanol are included in diesel and gasoline consumptions. The abbreviations used for fuel types are presented in Table 6.6.

Table 6.7 and 6.8 show the energy consumptions and their shares by fuel types in the base scenario. It can be seen that until 2031, diesel consumption increases, but beginning with 2036, diesel consumption decreases and the exposed energy demand is fulfilled mostly by gaseous hydrogen. On the other hand, beginning with 2016, the share of diesel consumption decreases year by year, especially due to higher growth in LPG and gasoline consumptions and continuous increase in electricity use in buses and light trucks. As the private car demand increases LPG and gasoline consumptions increase continuously due to lower costs of LPG and gasoline cars compared to cars in other technologies.

Table 6.6. Abbreviatons used for the fuel types.

Fuel Type	Definiton
TCNGBUS	CNG for buses and minibuses
TCNGHGV	CNG for heavy trucks and tractor trailers
TDIE	Diesel
TDIEBUS	Diesel for buses and minibuses
TDIECAR	Diesel for private cars and taxies
TDIEHGV	Diesel for heavy trucks and tractor trailers
TDIELGV	Diesel for light trucks
TDIERAIL	Diesel for all trains
TELC	Electricity
THDGAIR	Hydrogen for airplanes
THDGBUS	Hydrogen for buses and minibuses
THDGHGV	Hydrogen for heavy trucks and tractor trailers
TJETAIR	Jet fuel for airplanes
TLPGCAR	LPG for private cars and taxies
TPETCAR	Gasoline for private cars and taxies

Table 6.7. Energy consumptions by fuel types in the base scenario (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	5.8	6.2	4.9	5.5	5.8	3.4	4.0	0.0
Diesel	322.6	389.4	379.4	399.2	449.2	459.8	309.1	297.3	272.9	229.1
Electricity	1.1	1.4	4.9	11.3	19.0	27.7	37.8	48.9	59.0	70.6
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	69.1
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	110.2	153.3	207.8	281.2
Jet Fuel	15.2	22.3	32.2	49.1	61.4	94.0	110.3	151.1	171.0	171.0
LPG	54.6	97.5	113.2	130.6	153.7	162.2	195.4	221.5	272.7	317.6
Gasoline	110.2	90.0	113.4	140.2	160.4	175.7	192.6	226.0	268.5	337.7
Ethanol	0	0	0	0	0	0	0	0	0	0
Bio-Diesel	0	0	0	0	0	0	0	0	0	0
Total	503.8	604.0	649.0	736.5	848.5	924.8	961.2	1101.6	1255.9	1476.2

Table 6.8. Share of fuel types in the total energy consumptions in the base scenario (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	0.9	0.8	0.6	0.6	0.6	0.3	0.3	0.0
Diesel	64.0	64.5	58.5	54.2	52.9	49.7	32.2	27.0	21.7	15.5
Electricity	0.2	0.2	0.8	1.5	2.2	3.0	3.9	4.4	4.7	4.8
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	11.5	13.9	16.5	19.0
Jet Fuel	3.0	3.7	5.0	6.7	7.2	10.2	11.5	13.7	13.6	11.6
LPG	10.8	16.1	17.4	17.7	18.1	17.5	20.3	20.1	21.7	21.5
Gasoline	21.9	14.9	17.5	19.0	18.9	19.0	20.0	20.5	21.4	22.9
Ethanol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Regarding air transport, it can be seen that until 2051 jet fuel is the only fuel type, but in 2051, liquefied hydrogen fueled airplanes start being deployed. Since, hydrogen technology is more expensive than the technology in conventional airplanes; it can not enter the market until its price can compete with the conventional ones in 2051.

Conventional intercity and intracity buses use diesel fuel, but starting in 2016 electric powered vehicles begin to enter the market and gradually increase their share until 2051. This fuel switch causes a decrease in diesel consumption. Besides, CNG fueled intracity buses are used between 2011 and 2041, but in 2051 they are totally replaced with electric powered buses.

On the other hand, private cars use only diesel, LPG and gasoline throughout the planning horizon. Besides, until 2036, taxies use mostly LPG, but after 2016 electric powered taxies also begin to be used and they gradually dominate the market until 2051.

Throughout the planning horizon, heavy trucks and tractor trailers use diesel, but by 2036 hydrogen fueled trucks enter the market and they are also used until 2051. Regarding light trucks, the situation is a bit different. Like heavy trucks, they use diesel fuel, but by 2016 electric powered light trucks start entering the market and gradually increase their share until 2051.

Trains use varying shares of electricity and diesel fuel until 2051, but, as it can be seen in Appendix A, the share of electric powered trains increase in both freight and mainline passenger rail transport. Moreover, minibuses and all types of ships use diesel fuel until 2051.

The results indicate that the transport related CO_2 emissions for the year 2006 are 36121 kilo-tons (kt), gradually increasing and reaching to 76066 kt in 2051 (corresponding to an increase of 110% over 45 years). The trend of CO_2 emissions of the transport sector is shown in Figure 6.1. In addition, breakdown and share of CO_2 emissions by fuel types are presented in Table 6.9 and 6.10.

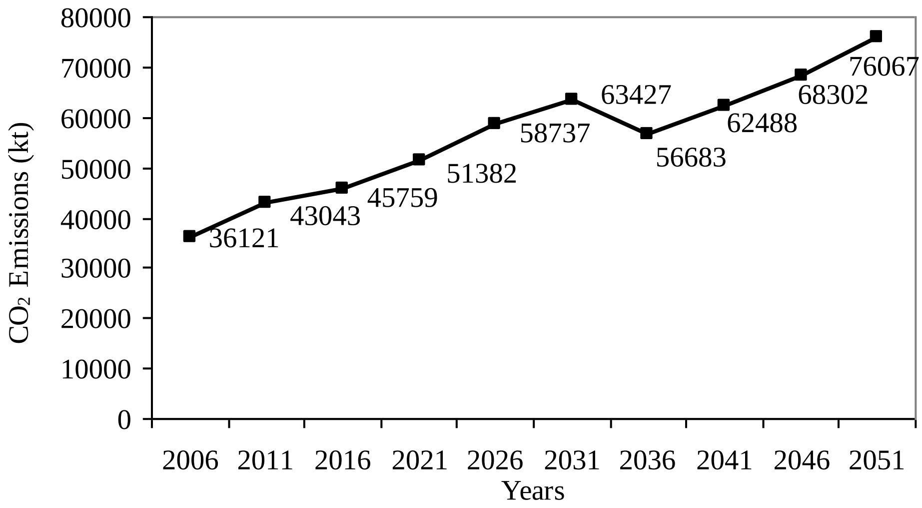

Figure 6.1. CO_2 emissions of the transport sector in the base scenario.

Table 6.9. CO_2 emissions by fuel types in the base scenario (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	328	348	273	309	326	190	226	0
Diesel	23908	28852	28114	29581	33285	34068	22906	22030	20220	16976
Jet Fuel	1055	1542	2234	3400	4257	6517	7641	10472	11852	11852
LPG	3443	6151	7144	8241	9696	10236	12330	13979	17208	20038
Gasoline	7716	6303	7938	9813	11227	12296	13479	15816	18796	23640
L. Hydrogen	0	0	0	0	0	0	0	0	0	3562
Total	36121	43043	45759	51382	58737	63427	56683	62488	68302	76067

Table 6.10. Share of fuel types in the total CO_2 emissions in the base scenario (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	0.7	0.7	0.5	0.5	0.6	0.3	0.3	0.0
Diesel	66.2	67.0	61.4	57.6	56.7	53.7	40.4	35.3	29.6	22.3
Jet Fuel	2.9	3.6	4.9	6.6	7.2	10.3	13.5	16.8	17.4	15.6
LPG	9.5	14.3	15.6	16.0	16.5	16.1	21.8	22.4	25.2	26.3
Gasoline	21.4	14.6	17.3	19.1	19.1	19.4	23.8	25.3	27.5	31.1
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

It can be seen that throughout the planning horizon, the total CO_2 emissions increase continuously. When the breakdown of CO_2 emissions of the transport sector is investigated, it can be seen that diesel emissions dominate the total emissions in 2006 and keep increasing until 2031. But, after 2031, diesel emissions decrease, with the use of gaseous hydrogen in heavy trucks and tractor trailers, and with the use of electricity in intercity and intracity buses.

In the model and the underlying RES, motor vehicles are assumed to use gaseous hydrogen fuels and they do not emit CO_2 gases. But, the hydrogen fuel used in air transport is liquid and emits CO_2 gases. Thus the increase in hydrogen usage in motor vehicles has a positive effect on emissions. Therefore, the decrease in diesel consumption with the increase in hydrogen and electricity use explain the sharp decrease in the total CO_2 emissions in 2036.

Beginning with 2036, LPG and gasoline usage keeps increasing due to the increase in total kilometers traveled by private cars and taxies. Besides, with the influence of the high increase in air transport, despite the decrease in diesel consumption, the total CO_2 emissions increase and reach 76.0 million tons in 2051.

Finally, for the comparison of sectors regarding the total energy consumptions and CO_2 emissions, Table 6.11 and 6.12 are presented.

Table 6.11. Share of sectors in the total energy consumptions in the base scenario (%).

Sector	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
Agriculture	0.5	0.4	0.4	0.3	59.9	0.3	0.3	0.3	0.3	0.2
Commercial	7.6	6.5	6.8	7.1	3.0	8.0	8.6	9.0	9.5	9.9
Industrial	42.9	41.3	43.2	45.3	19.2	50.8	54.6	57.7	60.7	63.3
Residential	30.2	34.9	35.0	33.8	12.8	29.6	26.7	23.7	20.9	18.4
Transport	18.9	16.9	14.7	13.4	5.1	11.3	9.8	9.2	8.6	8.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.12. Share of sectors in the total CO_2 emissions in the base scenario (kt).

Sector	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
Energy	36.4	29.4	34.8	34.1	38.7	41.6	44.6	46.9	47.2	47.6
Industrial	33.1	33.1	32.2	35.3	34.9	34.8	36.1	36.8	38.7	40.7
Residential	10.5	13.9	14.1	12.6	10.7	9.7	7.7	5.9	4.8	3.9
Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.9
Transport	13.9	12.0	9.2	8.3	7.3	6.1	4.4	3.8	3.4	3.1
Others	4.9	10.3	8.3	8.1	6.8	6.2	5.6	4.8	4.0	2.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Regarding the tables, it is seen that for both the total energy consumptions and CO_2 emissions, the share of transport sector gradually decreases from 2006 to 2051.

The reason is that in this study only the transport sector data is changed and the data for other sectors are kept unchanged. Since the sectoral growth rates in the original model are greater than the growth rate of the transport sector (which is re-estimated in this study more precisely), the difference between the sectors keeps increasing.

Besides, in this study, as explained in the fifth chapter, the transport sector is evaluated by 23 sub-modes (the ones with relevant travel demand data). Thus, the sub-modes, on which relevant data could not be obtained, are not considered in this study. Some of these sub-modes are; commercial private cars which are used by the employees of private companies, motorbikes, tractors and other vehicles used in agricultural activities, minibuses which are not used for public transport purposes (including school minibuses etc.), ships used in international maritime transport and the airplanes used in international flights. Therefore, these reasons cause the transport sector energy consumptions and emissions to grow slower than other sectors.

6.3. The Unary Case Scenarios

In this section, scenarios are created by unary combinations of the alternative cases (cases featuring single factor change) defined in Table 6.1 and their results are presented.

6.3.1. The 15% and 30% Emission Reduction Scenarios (2.1.1 and 3.1.1)

In these scenarios, constraints that impose emission reductions of 15% and 30% respectively are added on the base scenario. Since 2006 passed and 2011 is nearly over, the bounds are applied for the years 2016-2051. Except for these emission constraints, the rest of the model structure (and model data) are kept unchanged. Through these scenarios the behavior of the energy system under more stringent emission constraints can clearly be seen. The CO_2 emission values of the base scenario are taken as reference and for these alternative scenarios the constraints are defined by reducing the base scenarios emission levels by 15% and 30%., respectively. In a few cases, the model solution turned out to be infeasible because of these stringent requirements, in these cases, the upper bounds are slightly relaxed in order to eliminate the inconsistency.

For example, the 2016 value in the 30% scenario was calculated as 32031 kt, but, since the model run was infeasible, the emission constraint for 2016 is relaxed to 35000 kt at which level the model run became feasible. Table 6.13 displays the resulting upper bounds for the 2016-2051 period in both scenarios. The results of both scenarios are presented in Table 6.14-21. Besides, modal energy consumptions by fuel types are presented for these scenarios in Appendix A.

Table 6.13. CO_2 emission bounds in the 15% and 30% scenarios.

Scenario	2016	2021	2026	2031	2036	2041	2046	2051
15%	38,895	43,675	49,927	53,913	48,180	53,115	58,057	64,657
30%	35,000	35,967	41,116	44,399	39,678	43,741	47,811	53,247

Table 6.14. Energy consumptions by fuel types in scenario 2.1.1 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	5.4	6.4	4.7	5.3	6.1	3.5	3.8	0.0
Diesel	322.6	389.4	366.5	395.9	426.5	437.4	306.3	278.3	209.1	136.8
Electricity	1.1	1.4	6.0	18.7	26.4	35.0	60.8	65.7	75.8	87.4
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	69.1
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	110.2	153.3	207.8	281.2
Jet Fuel	15.2	22.3	32.2	47.4	61.4	90.3	108.1	148.9	171.0	171.0
LPG	54.6	97.5	113.2	116.8	139.9	99.9	98.4	138.3	189.5	282.8
Gasoline	110.2	85.0	29.4	47.5	71.1	123.5	163.6	189.4	264.9	303.7
Ethanol	0.0	0.0	74.7	74.7	71.0	69.2	29.7	49.5	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	3.2	19.9	19.9	0.0	19.9	63.6	92.3
Total	503.8	599.0	627.4	710.5	820.8	880.5	883.1	1046.7	1185.5	1424.3

Table 6.15. Share of fuel types in the total energy consumptions in scenario 2.1.1 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	0.9	0.9	0.6	0.6	0.7	0.3	0.3	0.0
Diesel	64.0	65.0	58.4	55.7	52.0	49.7	34.7	26.6	17.6	9.6
Electricity	0.2	0.2	1.0	2.6	3.2	4.0	6.9	6.3	6.4	6.1
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	12.5	14.6	17.5	19.7
Jet Fuel	3.0	3.7	5.1	6.7	7.5	10.2	12.2	14.2	14.4	12.0
LPG	10.8	16.3	18.0	16.4	17.0	11.3	11.1	13.2	16.0	19.9
Gasoline	21.9	14.2	4.7	6.7	8.7	14.0	18.5	18.1	22.3	21.3
Ethanol	0.0	0.0	11.9	10.5	8.6	7.9	3.4	4.7	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	0.5	2.4	2.3	0.0	1.9	5.4	6.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.16. Energy consumptions by fuel types in scenario 3.1.1 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	5.4	6.4	5.0	5.1	6.0	3.5	3.7	0.0
Diesel	322.6	388.4	358.9	307.3	319.7	323.7	250.1	215.9	108.9	43.7
Electricity	1.1	1.4	7.8	14.2	22.0	30.6	65.2	78.3	83.9	83.9
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	72.5	141.6
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	110.2	153.3	213.8	302.7
Jet Fuel	15.2	22.3	32.2	47.4	61.4	90.3	108.1	148.9	110.4	110.4
LPG	54.6	99.6	93.0	151.5	184.2	137.1	97.9	118.6	170.8	246.8
Gasoline	110.2	85.0	0.0	0.0	18.2	74.6	102.1	139.2	248.1	278.4
Ethanol	0.0	0.0	105.4	105.4	101.2	105.4	77.1	81.9	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	80.0	132.5	132.5	55.5	82.5	163.9	184.5
Total	503.8	600.1	602.7	712.1	844.1	899.2	872.1	1022.2	1175.9	1391.9

Table 6.17. Share of fuel types in the total energy consumptions in scenario 3.1.1 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	0.9	0.9	0.6	0.6	0.7	0.3	0.3	0.0
Diesel	64.0	64.7	59.5	43.1	37.9	36.0	28.7	21.1	9.3	3.1
Electricity	0.2	0.2	1.3	2.0	2.6	3.4	7.5	7.7	7.1	6.0
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.2	10.2
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	12.6	15.0	18.2	21.7
Jet Fuel	3.0	3.7	5.3	6.7	7.3	10.0	12.4	14.6	9.4	7.9
LPG	10.8	16.6	15.4	21.3	21.8	15.2	11.2	11.6	14.5	17.7
Gasoline	21.9	14.2	0.0	0.0	2.2	8.3	11.7	13.6	21.1	20.0
Ethanol	0.0	0.0	17.5	14.8	12.0	11.7	8.8	8.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	11.2	15.7	14.7	6.4	8.1	13.9	13.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

In Table 6.14-17, the energy consumptions and their shares by fuel types are presented for both the 15% and 30% emission reduction scenarios (2.1.1 and 3.1.1). It can be seen that, as in the base scenario, up to 2031, diesel consumption keeps increasing but, after 2036 it falls. This difference is supplied mostly by gaseous hydrogen used in heavy trucks and tractor trailers. Besides, bio-diesel is also used intensively throughout the planning horizon instead of conventional diesel fuel. In addition, compared to the base scenario, electricity consumption is generally higher in both scenarios.

Besides, it can be seen that, LPG and gasoline consumptions are lower than the base scenario in the 30% emission reduction scenario. Moreover, in this scenario, ethanol (which is a zero carbon fuel) is introduced to the market and used in private cars (instead of gasoline), especially between 2016 and 2031. After 2036, with the satisfaction of the emission constraint, ethanol consumption decreases and the share of conventional gasoline increases again (since its cost is lower than ethanol’s)

Different from the base scenario, electricity consumption increases due to the electric powered private cars which are introduced to the market after 2016. The intracity buses use diesel and electricity as realized in the base scenario, but in the last 10 years of the planning horizon, they begin to use gaseous hydrogen as well. Regarding air transport, although hydrogen consumption does not change in the 15% reduction scenario, it increases in the 30% scenario. Additionally, the consumptions of fuel types do not change in the trains, ships, minibuses, light trucks.

It should be noted that in CO_2 reduction scenarios and in alternative scenarios that include CO_2 emission reduction, ethanol is used as a substitute for conventional gasoline fuel. In some scenarios (such as the 30% emission reduction scenario) gasoline is even fully substituted by ethanol. This can be considered similar to the case currently being implemented in Brasil, where most of the new cars and light vehicles are flexible fuel ones that can run on any proportion of gasoline and hydrous ethanol.

Table 6.18. CO_2 emissions by fuel types in scenario 2.1.1 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	303	357	264	299	341	196	212	0
Diesel	23908	28852	27154	29337	31602	32408	22693	20619	15493	10135
Jet Fuel	1055	1542	2234	3283	4257	6254	7489	10319	11852	11852
LPG	3443	6151	7144	7373	8827	6305	6208	8725	11955	17846
Gasoline	7716	5950	2060	3325	4977	8646	11449	13255	18545	21262
L. Hydrogen	0	0	0	0	0	0	0	0	0	3562
Total	36121	42689	38895	43675	49927	53913	48180	53115	58057	64657

Table 6.19. Share of fuel types in the total CO_2 emissions in scenario 2.1.1 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	0.8	0.8	0.5	0.6	0.7	0.4	0.4	0.0
Diesel	66.2	67.6	69.8	67.2	63.3	60.1	47.1	38.8	26.7	15.7
Jet Fuel	2.9	3.6	5.7	7.5	8.5	11.6	15.5	19.4	20.4	18.3
LPG	9.5	14.4	18.4	16.9	17.7	11.7	12.9	16.4	20.6	27.6
Gasoline	21.4	13.9	5.3	7.6	10.0	16.0	23.8	25.0	31.9	32.9
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.20. CO_2 emissions by fuel types in scenario 3.1.1 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	303	357	282	285	336	198	207	0
Diesel	23908	28778	26595	22767	23686	23987	18529	15996	8072	3241
Jet Fuel	1055	1542	2234	3283	4257	6254	7489	10319	7648	7648
LPG	3443	6284	5867	9560	11621	8651	6176	7485	10778	15574
Gasoline	7716	5950	0	0	1270	5221	7148	9743	17370	19486
L. Hydrogen	0	0	0	0	0	0	0	0	3736	7298
Total	36121	42749	35000	35967	41116	44399	39678	43741	47811	53247

Table 6.21. Share of fuel types in the total CO_2 emissions in scenario 3.1.1 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	0.9	1.0	0.7	0.6	0.8	0.5	0.4	0.0
Diesel	66.2	67.3	76.0	63.3	57.6	54.0	46.7	36.6	16.9	6.1
Jet Fuel	2.9	3.6	6.4	9.1	10.4	14.1	18.9	23.6	16.0	14.4
LPG	9.5	14.7	16.8	26.6	28.3	19.5	15.6	17.1	22.5	29.2
Gasoline	21.4	13.9	0.0	0.0	3.1	11.8	18.0	22.3	36.3	36.6
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8	13.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Results show that in both scenarios the total emissions are realized at the upper bounds defined by the constraints, which means that these emission constraints greatly impact the energy system and force it to invest in cleaner vehicle technologies and fuels.

In these scenarios, the emissions in 2006 are the same as the emissions in the base scenario, but due to the bounds applied in and after 2016, 2011 is affected and the emissions fall slightly in 2011. For the rest of the planning horizon, the emission values decrease exactly by 15% and 30%, as dictated by the emission bounds. But, as can be seen from Figure 6.2 and 6.3, the growth behaviour in the alternative scenarios are similar to the ones in the base scenario. For example, in 2036 the total emissions decrease due to the fuel switch from diesel to hydrogen, as explained in the base scenario.

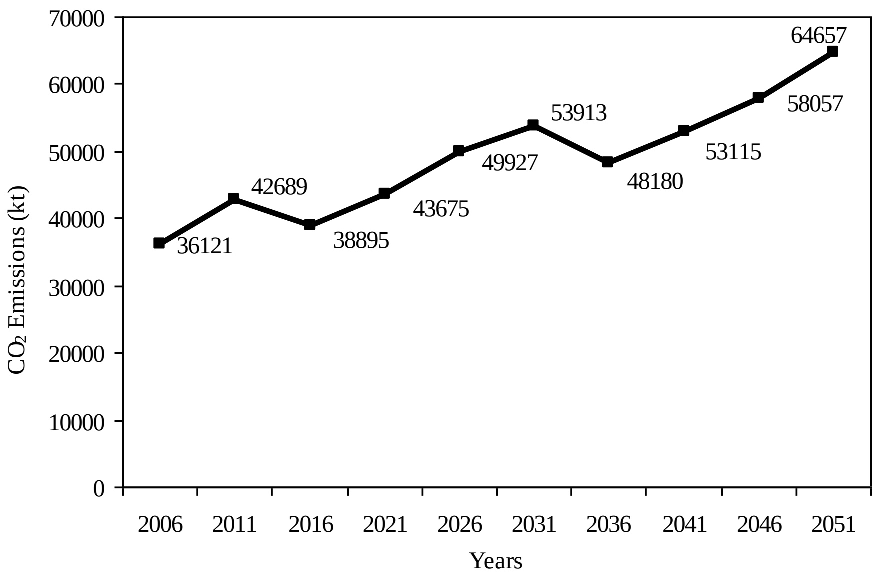

Figure 6.2. CO_2 emissions of the transport sector in scenario 2.1.1.

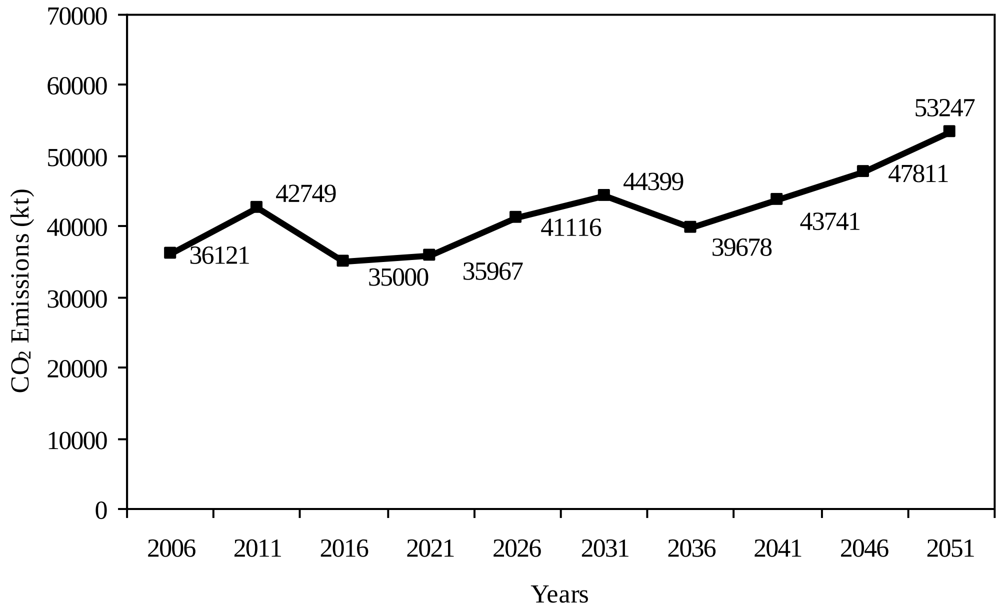

Figure 6.3. CO_2 emissions of the transport sector in scenario 3.1.1.

In addition, regarding the breakdown of CO_2 emissions by fuel types, it can be inferred that all fossil fuel emissions decrease. But, gasoline emissions decrease much more dramatically, especially between 2016 and 2031, due to the intensive use of ethanol (which is a zero carbon fuel) in gasoline fueled vehicles. But, as time passes, ethanol usage decreases and completely ends in 2041 again leading to the increase in emissions from gasoline consumption. This is because the emission target is satisfied by other fuel types (especially gaseous hydrogen) and gasoline consumption is again increased (due to its lower cost). Besides, diesel vehicles begin to use bio-diesel after 2021 and gaseous hydrogen (especially heavy trucks and tractor trailers) after 2036. Thus, emissions from diesel consumption decrease.

6.3.2. The 10% and 20% Modal Shift Scenarios (1.2.1 and 1.3.1)

In these scenarios, the demand data are altered for passenger and freight transport modes. This is done under the key assumption of these scenarios that investments to rail, air and maritime transportation systems will make these modes much more attractive, leading to the assumed percentage shifts in passenger and freight amounts (in passenger and ton kilometer units) towards these more attractive transport modes. The passenger transport is studied in two parts; urban and intercity passenger transport.

In urban areas, it is assumed that the modal shift is realized from private cars and minibuses to public transport vehicles such as intracity buses and metro. Whereas, in intercity traffic, the shift is assumed to occur from private cars and intercity buses to airplanes and high-speed trains. On the other hand, regarding freight transport, the modal shift is assumed to occur from road transport (i.e. heavy trucks, tractor trailers and light trucks) to rail and maritime transport.

The methodology used to calculate the shift amounts are based on passenger-kilometers in passenger transport and ton-kilometers in freight transport. The vehicle-kilometers saved from the original modes are first converted to passenger and ton kilometers based on the average passenger and/or freight tonnage of a typical vehicle in the original mode. Then these passenger and ton kilometer values are distributed to the target modes based on the assumed modal shift percentages. Finally, the shifts into target modes are reconverted into vehicle kilometer units based on the average passenger and/or freight tonnage of a typical vehicle in the target mode. The conversion rates and multipliers used in this methodology are based on statistics, trends and policies on vehicle capacities, fill rates and targeted modal shift levels. The assumed average capacity values for each sub-mode (for both passenger and freight transport) are presented in Table 6.22. Private cars are divided into two groups; intercity and urban, in which average passenger capacities are assumed as 3 and 2, respectively as displayed.

Table 6.22. The average freight and passenger capacities by sub-modes.

Freight Capacity (Tons/Vehicle)		Passenger Capacity (Passengers/Vehicle)	
TH1	20	TC [a]	3
TH2	30	TC [b]	2
TL	10	TB3	15
TRF	1000	TB2	70
TSKY	2300	TRMET	600
TSDY	5000	TB1	30
TSKT	6500	TA	120
TSTK	1800	TRH	320

For example, in 2016, estimated total travel distance for heavy trucks is 13.1 billion kilometers. In the 10% modal shift scenario, the revised demand kilometer is calculated as 11.8 billion kilometers (90% of 13.1). The difference (1.3 billion kilometers) is then multiplied by truck capacity (20 tons) in order to find ton kilometer value. This value is distributed to maritime and railway sectors by an estimate of 70%-30% regarding the realized ton kilometer values in Turkey. Finally, distributed ton kilometer values for maritime and railway sector are re-converted to vehicle kilometers by dividing the assumed tonnage capacities presented in Table 6.22. The calculations are conducted with this methodology both for freight and passenger transport.

The results of both scenarios are presented in Table 6.23-30. Besides, modal energy consumptions by fuel types are presented for these scenarios in Appendix A.

Table 6.23. Energy consumptions by fuel types in scenario 1.2.1 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	3.47	6.5	6.89	5.34	5.92	6.29	3.67	4.34	0
Diesel	322.64	389.37	359.33	378.06	424.43	432.84	297.61	286.54	267.57	232.28
Electricity	1.12	1.41	6.42	13.97	23.46	34.14	46.27	60.44	72.78	87.39
L.Hydrogen	0	0	0	0	0	0	0	0	0	76.01
G.Hydrogen	0	0	0	0	0	0	99.2	137.99	187	253.04
Jet Fuel	15.22	22.25	65.01	82.25	90.03	121.64	136.85	182.99	205.56	205.56
LPG	54.56	97.47	104.45	119.6	140.24	145.97	176.3	200.2	246.09	285.48
Gasoline	110.24	90.04	102.88	127.48	145.67	157.52	173.69	203.24	241.54	303.77
Ethanol	0	0	0	0	0	0	0	0	0	0
Bio-Diesel	0	0	0	0	0	0	0	0	0	0
Total	503.78	604.01	644.59	728.25	829.17	898.03	936.21	1075.07	1224.88	1443.53

Table 6.24. Share of fuel types in the total energy consumptions in scenario 1.2.1 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	1.0	0.9	0.6	0.7	0.7	0.3	0.4	0.0
Diesel	64.0	64.5	55.7	51.9	51.2	48.2	31.8	26.7	21.8	16.1
Electricity	0.2	0.2	1.0	1.9	2.8	3.8	4.9	5.6	5.9	6.1
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	10.6	12.8	15.3	17.5
Jet Fuel	3.0	3.7	10.1	11.3	10.9	13.5	14.6	17.0	16.8	14.2
LPG	10.8	16.1	16.2	16.4	16.9	16.3	18.8	18.6	20.1	19.8
Gasoline	21.9	14.9	16.0	17.5	17.6	17.5	18.6	18.9	19.7	21.0
Ethanol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.25. Energy consumptions by fuel types in scenario 1.3.1 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	3.47	7.15	7.58	5.81	6.33	6.77	3.94	4.64	0
Diesel	322.64	389.37	339.06	357.05	399.29	406.63	286.01	275.78	262.29	235.46
Electricity	1.12	1.41	7.93	16.65	27.92	40.64	54.71	71.95	83.6	83.59
L.Hydrogen	0	0	0	0	0	0	0	0	0	82.94
G.Hydrogen	0	0	0	0	0	0	88.18	122.67	170.18	252.61
Jet Fuel	15.22	22.25	97.24	114.91	118.65	149.19	165.63	217.06	240.11	240.11
LPG	54.56	97.47	98.2	111.72	130.04	129.93	157.16	178.28	218.81	253.53
Gasoline	110.24	90.04	89.76	111.55	127.76	138.12	154.61	180.95	214.97	270.6
Ethanol	0	0	0	0	0	0	0	0	0	0
Bio-Diesel	0	0	0	0	0	0	0	0	0	0
Total	503.78	604.01	639.34	719.46	809.47	870.84	913.07	1050.63	1194.6	1418.84

Table 6.26. Share of fuel types in the total energy consumptions in scenario 1.3.1 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	1.1	1.1	0.7	0.7	0.7	0.4	0.4	0.0
Diesel	64.0	64.5	53.0	49.6	49.3	46.7	31.3	26.2	22.0	16.6
Electricity	0.2	0.2	1.2	2.3	3.4	4.7	6.0	6.8	7.0	5.9
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	9.7	11.7	14.2	17.8
Jet Fuel	3.0	3.7	15.2	16.0	14.7	17.1	18.1	20.7	20.1	16.9
LPG	10.8	16.1	15.4	15.5	16.1	14.9	17.2	17.0	18.3	17.9
Gasoline	21.9	14.9	14.0	15.5	15.8	15.9	16.9	17.2	18.0	19.1
Ethanol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

From the energy consumption tables, it can be seen that diesel consumptions decrease in both scenarios compared to the base scenario, due to the reduced travel demand of intercity buses, minibuses, and private cars which use diesel fuel. In fact, with the increased freight demand in rail and maritime transport (shifted from road transport vehicles like trucks etc.) and passenger demand in intracity buses, diesel consumption also increases in these sectors. But, since the saved diesel energy is more than this increase (except for 2051), diesel consumptions decrease in both scenarios. Compared to the base scenario, in 2051, diesel consumption is a bit higher in both scenarios, because, the increase in diesel consumption (in maritime and rail freight transport) exceeds the saved amount in road transport (trucks, intercity buses, private cars etc.) Besides, as in the base scenario, some of the decrease in diesel fuel consumption realized in 2036 is due to the fuel switch from diesel to gaseous hydrogen.

Regarding the electricity consumption, it can be seen that with the increased demand in electric powered freight trains, high-speed passenger trains and metro, electricity consumption increases in both scenario 1.2.1 and 1.3.1, compared to the base scenario. In addition, with the reduced demand in private cars, LPG and gasoline consumptions decrease in these scenarios. Moreover, with the increased intracity bus demand, in the 10% scenario, electricity is used as an alternative to diesel fuel. But, in the 20% scenario, hydrogen is also deployed in 2046 and 2051, as an alternative to electricity and diesel. Regarding air transport, it is seen that jet fuel consumption increases throughout the planning horizon due to the shifted demand from private cars and intercity buses to airplanes, and as a consequence of which liquefied hydrogen consumption also increases in 2051.

Table 6.27. CO_2 emissions by fuel types in scenario 1.2.1 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	365	386	300	332	353	206	244	0
Diesel	23908	28852	26625	28014	31451	32073	22054	21232	19825	17211
Jet Fuel	1055	1542	4505	5700	6239	8430	9484	12681	14246	14246
LPG	3443	6151	6591	7547	8850	9211	11125	12633	15528	18014
Gasoline	7716	6303	7202	8924	10197	11027	12158	14226	16908	21264
L. Hydrogen	0	0	0	0	0	0	0	0	0	3919
Total	36121	43043	45288	50572	57036	61072	55173	60977	66751	74654

Table 6.28. Share of fuel types in the total CO_2 emissions in scenario 1.2.1 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	0.8	0.8	0.5	0.5	0.6	0.3	0.4	0.0
Diesel	66.2	67.0	58.8	55.4	55.1	52.5	40.0	34.8	29.7	23.1
Jet Fuel	2.9	3.6	9.9	11.3	10.9	13.8	17.2	20.8	21.3	19.1
LPG	9.5	14.3	14.6	14.9	15.5	15.1	20.2	20.7	23.3	24.1
Gasoline	21.4	14.6	15.9	17.6	17.9	18.1	22.0	23.3	25.3	28.5
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.29. CO_2 emissions by fuel types in scenario 1.3.1 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	401	425	326	355	380	221	260	0
Diesel	23908	28852	25125	26459	29587	30131	21193	20436	19435	17446
Jet Fuel	1055	1542	6739	7963	8222	10339	11478	15043	16639	16639
LPG	3443	6151	6197	7050	8206	8199	9916	11249	13806	15998
Gasoline	7716	6303	6284	7808	8942	9668	10823	12666	15049	18942
L. Hydrogen	0	0	0	0	0	0	0	0	0	4276
Total	36121	43043	44745	49706	55284	58692	53790	59615	65190	73302

Table 6.30. Share of fuel types in the total CO_2 emissions in scenario 1.3.1 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	0.9	0.9	0.6	0.6	0.7	0.4	0.4	0.0
Diesel	66.2	67.0	56.2	53.2	53.5	51.3	39.4	34.3	29.8	23.8
Jet Fuel	2.9	3.6	15.1	16.0	14.9	17.6	21.3	25.2	25.5	22.7
LPG	9.5	14.3	13.8	14.2	14.8	14.0	18.4	18.9	21.2	21.8
Gasoline	21.4	14.6	14.0	15.7	16.2	16.5	20.1	21.2	23.1	25.8
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

When the emission results are investigated, it is seen that the conducted modal shifts have positive effects on the CO_2 emissions of the transport sector. As displayed in Table 6.27 and 6.29 and Figure 6.4 and 6.5, in both scenarios, the level of CO_2 emissions decrease significantly in each year and the gain increases as the shift ratio is increased from 10 to 20%. On the other hand, the general trend is similar with that of the base scenario.

If the breakdown of the total CO_2 emissions is further investigated, it is seen that the diesel fuel emissions decrease (except for 2051) compared to the base scenario, consistent with the reasons explained in the energy consumption part. Besides, LPG and gasoline emissions also decrease due to the reduced travel demand (or energy consumptions).in private cars. Moreover, emissions from CNG consumption slightly increase due to the increased demand in intracity buses.

Regarding air transport, it is seen that CO_2 emissions from jet fuel and liquefied hydrogen increase, consistent with the increased air transport demand, which is shifted from intercity buses and private cars.

In short, throughout the planning horizon, although the emissions from jet fuel, liquefied hydrogen and CNG fuels increase, savings from diesel, LPG and gasoline consumption compensate that increase and cause the total emission levels to drop in these two scenarios.

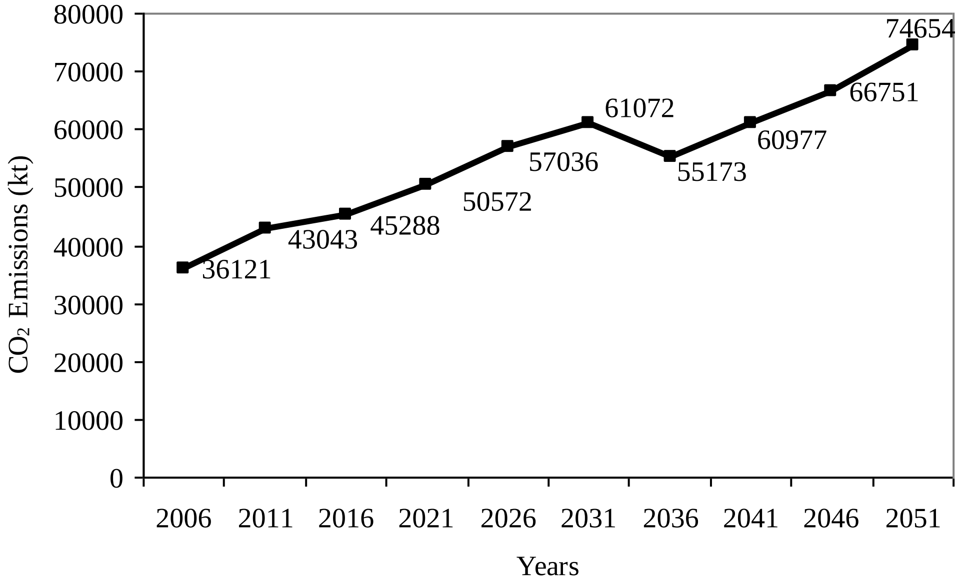

Figure 6.4. CO_2 emissions of the transport sector in scenario 1.2.1.

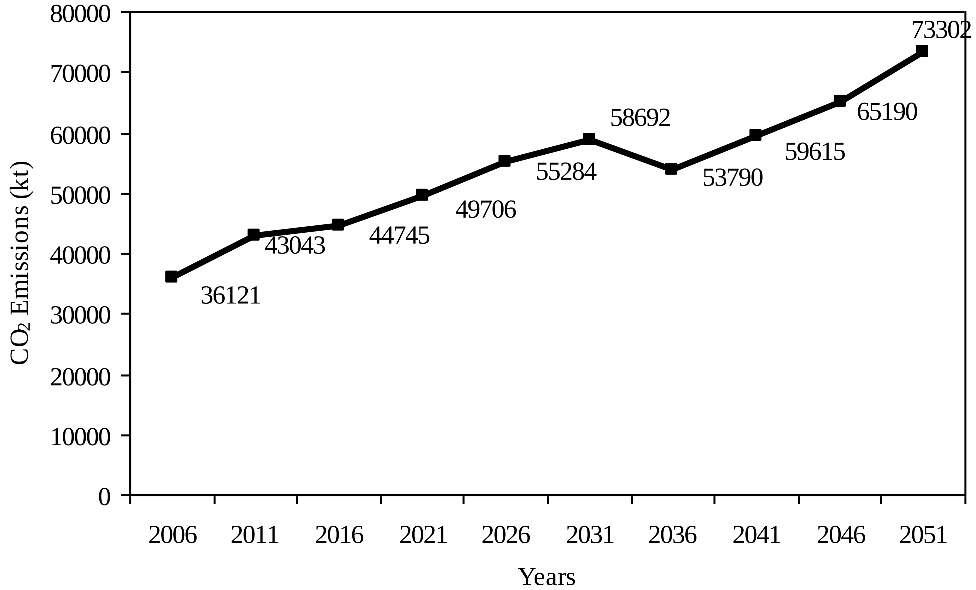

Figure 6.5. CO_2 emissions of the transport sector in scenario 1.3.1.

6.3.3. The 15-30% Efficiency Improvement and 20-40% Fuel Price Increase Scenarios (1.1.2 and 1.1.3)

These scenarios investigate the impact of vehicle efficiency improvements and fuel price increases on the transport sector and its CO_2 emissions. In scenario 1.1.2 efficiencies of vehicles in sub-modes TC1, TC2, TC3 and TC4 are assumed to have improved by 15% beyond the year 2011, while price of fuels (imported and refined oil products such as, diesel, LPG, gasoline and jet fuel etc.) are assumed to have increased by 20% beyond the year 2011. In scenario 1.1.3, these two rates are assumed to be 30% and 40%, respectively. The results of both scenarios are presented in Table 6.31-38. Besides, modal energy consumptions by fuel types are presented for these scenarios in Appendix A.

Table 6.31. Energy consumptions by fuel types in scenario 1.1.2.(PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	5.8	6.2	40.9	41.6	5.8	3.4	4.0	0.0
Diesel	322.6	389.4	368.1	398.5	422.6	430.8	298.6	215.9	85.3	43.7
Electricity	1.1	1.4	4.9	11.3	19.0	27.7	42.1	53.2	63.3	74.9
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	128.7	273.4
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	110.2	153.3	207.8	281.2
Jet Fuel	15.2	22.3	32.2	49.1	61.4	94.0	108.1	148.9	63.3	0.0
LPG	54.6	97.5	111.3	126.4	146.3	141.7	170.3	192.9	237.1	321.8
Gasoline	110.2	90.0	110.9	135.5	154.3	157.0	162.3	191.5	216.4	230.7
Ethanol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	74.8	180.6	180.6
Total	503.8	604.0	633.3	727.0	844.5	892.7	897.4	1033.8	1186.5	1406.2

Table 6.32. Share of fuel types in the total energy consumptions in scenario 1.1.2 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	0.9	0.9	4.8	4.7	0.6	0.3	0.3	0.0
Diesel	64.0	64.5	58.1	54.8	50.0	48.3	33.3	20.9	7.2	3.1
Electricity	0.2	0.2	0.8	1.6	2.3	3.1	4.7	5.1	5.3	5.3
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.8	19.4
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	12.3	14.8	17.5	20.0
Jet Fuel	3.0	3.7	5.1	6.7	7.3	10.5	12.0	14.4	5.3	0.0
LPG	10.8	16.1	17.6	17.4	17.3	15.9	19.0	18.7	20.0	22.9
Gasoline	21.9	14.9	17.5	18.6	18.3	17.6	18.1	18.5	18.2	16.4
Ethanol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.2	15.2	12.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.33. Energy consumptions by fuel types in scenario 1.1.3 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	44.2	96.5	152.8	217.2	5.8	3.4	4.0	0.0
Diesel	322.6	389.4	339.5	337.4	310.0	169.1	153.4	144.4	33.7	43.7
Electricity	1.1	1.4	4.9	11.3	19.0	27.7	42.1	59.7	69.8	81.3
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.8	204.3	273.4
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	110.2	153.3	207.8	281.2
Jet Fuel	15.2	22.3	32.8	49.6	61.4	93.5	108.1	108.1	0.0	0.0
LPG	54.6	97.5	109.8	123.2	140.7	126.0	151.0	170.8	242.5	317.4
Gasoline	110.2	90.0	109.1	131.8	149.6	143.0	147.2	159.1	157.9	169.6
Ethanol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	0.0	37.8	141.3	141.3	141.3	227.2	177.0
Total	503.8	604.0	640.2	749.8	871.3	917.6	859.1	984.8	1147.1	1343.5

Table 6.34. Share of fuel types in the total energy consumptions in scenario 1.1.3 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	6.9	12.9	17.5	23.7	0.7	0.3	0.4	0.0
Diesel	64.0	64.5	53.0	45.0	35.6	18.4	17.9	14.7	2.9	3.3
Electricity	0.2	0.2	0.8	1.5	2.2	3.0	4.9	6.1	6.1	6.1
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	17.8	20.3
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	12.8	15.6	18.1	20.9
Jet Fuel	3.0	3.7	5.1	6.6	7.0	10.2	12.6	11.0	0.0	0.0
LPG	10.8	16.1	17.2	16.4	16.1	13.7	17.6	17.3	21.1	23.6
Gasoline	21.9	14.9	17.0	17.6	17.2	15.6	17.1	16.2	13.8	12.6
Ethanol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	0.0	4.3	15.4	16.4	14.3	19.8	13.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

From the energy consumption tables, it can be seen that diesel consumptions decrease in both scenarios compared to the base scenario. This decrease can be explained by two reasons, first, due to the increased diesel fuel prices, fuel switch is realized from conventional diesel to bio-diesel in all vehicle types and also switch to CNG in intracity buses, trucks and tractor trailers; second, due to the decreased energy consumptions values realized by the increased auto fuel efficiencies. Diesel consumptions for most of the vehicles are the same with the base scenario. But, for trucks and tractor trailers, CNG is also used instead of diesel between 2016 and 2031 in scenario 1.1.3 (between 2026 and 2031 in scenario 1.1.2). Besides, bio-diesel is used in diesel fueled vehicles between 2026 and 2051 in scenario 1.1.3 (between 2041 and 2051 in scenario 1.1.2).

Regarding private cars, the energy consumptions decrease for gasoline and LPG fuel types. Except for the TC1 sub mode (which is partially replaced by electric powered vehicles after 2036), gasoline and LPG are not replaced with any alternative fuel types. Thus, it can be inferred that the decrease in gasoline and LPG consumptions are due to increased auto fuel efficiencies rather than fuel prices. Electricity consumptions slightly increase compared to the base scenario due to the additional electricity used in TC1 sub-mode.

Except for trucks and tractor trailers, CNG is used more in intracity buses due to the increased diesel fuel prices. The total CNG consumption of intracity buses in the alternative scenarios 1.1.2 and 1.1.3 increase from the level in the base scenario.

Table 6.35. CO_2 emissions by fuel types in scenario 1.1.2 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	328	348	2297	2332	326	190	226	0
Diesel	23908	28852	27277	29532	31313	31920	22128	15996	6320	3241
Jet Fuel	1055	1542	2234	3400	4257	6517	7489	10319	4387	0
LPG	3443	6151	7023	7977	9234	8943	10746	12169	14964	20304
Gasoline	7716	6303	7767	9482	10799	10987	11357	13404	15146	16147
L. Hydrogen	0	0	0	0	0	0	0	0	6634	14095
Total	36121	43043	44628	50738	57899	60698	52046	52079	47676	53787

Table 6.36. Share of fuel types in the total CO_2 emissions in scenario 1.1.2 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	0.7	0.7	4.0	3.8	0.6	0.4	0.5	0.0
Diesel	66.2	67.0	61.1	58.2	54.1	52.6	42.5	30.7	13.3	6.0
Jet Fuel	2.9	3.6	5.0	6.7	7.4	10.7	14.4	19.8	9.2	0.0
LPG	9.5	14.3	15.7	15.7	15.9	14.7	20.6	23.4	31.4	37.7
Gasoline	21.4	14.6	17.4	18.7	18.7	18.1	21.8	25.7	31.8	30.0
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.9	26.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.37. CO_2 emissions by fuel types in scenario 1.1.3 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	2478	5412	8570	12184	326	190	226	0
Diesel	23908	28852	25156	25004	22970	12533	11368	10696	2495	3241
Jet Fuel	1055	1542	2272	3437	4257	6477	7489	7489	0	0
LPG	3443	6151	6929	7774	8878	7947	9528	10779	15301	20025
Gasoline	7716	6303	7635	9227	10470	10007	10303	11136	11054	11872
L. Hydrogen	0	0	0	0	0	0	0	2310	10532	14095
Total	36121	43043	44470	50855	55145	49149	39013	42599	39609	49233

Table 6.38. Share of fuel types in the total CO_2 emissions in scenario 1.1.3 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	5.6	10.6	15.5	24.8	0.8	0.4	0.6	0.0
Diesel	66.2	67.0	56.6	49.2	41.7	25.5	29.1	25.1	6.3	6.6
Jet Fuel	2.9	3.6	5.1	6.8	7.7	13.2	19.2	17.6	0.0	0.0
LPG	9.5	14.3	15.6	15.3	16.1	16.2	24.4	25.3	38.6	40.7
Gasoline	21.4	14.6	17.2	18.1	19.0	20.4	26.4	26.1	27.9	24.1
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	26.6	28.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

When the emission results are investigated, it is seen that the efficiency improvement and fuel price changes have positive effects on the CO_2 emissions of the transport sector. As displayed in Table 6.35 and 6.37 and Figure 6.6 and 6.7, in both scenarios, the level of CO_2 emissions decrease in each year and the gain increases as the efficiency improvement and fuel price increase rates are increased from 15%-20% to 30%-40%.

When the total CO_2 emissions are analyzed for these scenarios, it is seen that the emissions continue to grow in a similar trend with the base scenario until 2031 and 2026 in scenarios 1.1.2 and 1.1.3, respectively. Then, CO_2 emissions levels drop significantly compared to the base scenario. In these two scenarios, the emissions of diesel, LPG and gasoline fuels decrease due to the increased efficiencies and decreased fuel consumption. Besides, jet fuel emissions decrease due to the more intensive use of liquefied hydrogen in airplanes. Another important point is that, in both scenarios, CO2 emissions from CNG consumptions increase dramatically, due to its use in heavy trucks and tractor trailers.

In scenario 1.1.2, the total emissions slightly decrease from 2016 to 2031, due to the factors explained in the paragraph on energy consumption (increased efficiencies, reduced fossil fuel consumptions and increased environment friendly fuel types such as electricity and CNG). Then, emissions decrease dramatically in 2036 and slightly increase until 2051. This dramatic decrease is mostly due to the reduced diesel emissions which stem from gaseous hydrogen use (as in the base scenario) in heavy trucks and tractor trailers and bio-diesel consumption instead of conventional diesel fuel. Likewise, CO_2 emissions in scenario 1.1.3 follow the same trend with scenario 1.1.2. But, since bio-diesel is used more intensively in this scenario, emission levels are lower than those of scenario 1.1.2.

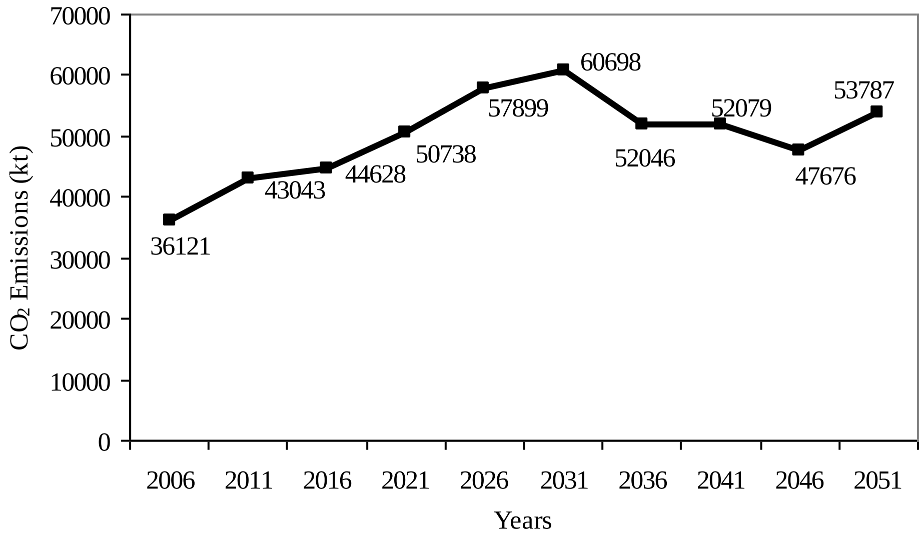

Figure 6.6. CO_2 emissions of the transport sector in scenario 1.1.2.

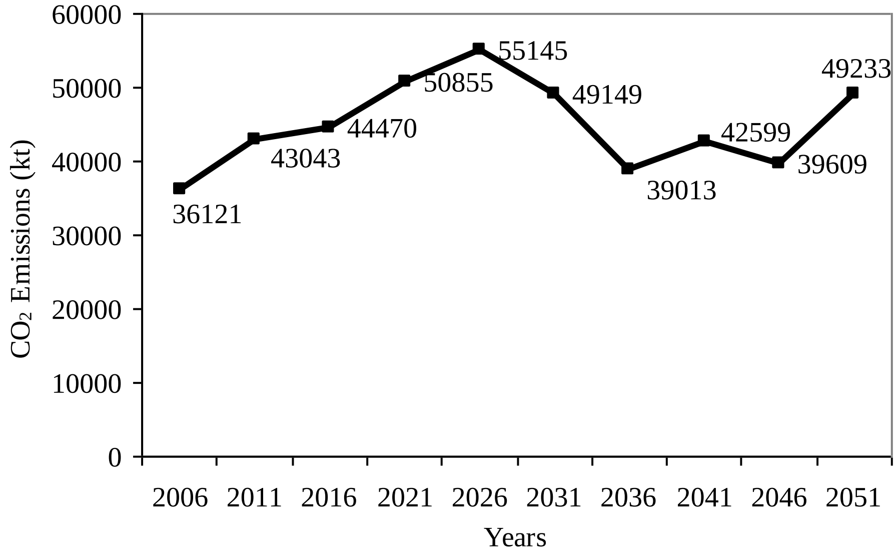

Figure 6.7. CO_2 emissions of the transport sector in scenario 1.1.3.

6.4. The Binary Case Scenarios

In this section, scenarios are created by binary combinations of the alternative cases (cases different from 0% change) defined in Table 6.1 and their results are presented.

6.4.1. The 15-30% Efficiency Improvement and 20-40% Fuel Price Increase Scenarios with the 10% Modal Shift Scenario. (1.2.2 and 1.2.3)

The 15%-30% and the 20%-40% efficiency improvement and fuel price increase scenarios are integrated with the 10% modal shift scenario to generate the dual change scenarios 1.2.2 and 1.2.3. The modal shift, efficiency improvement and the fuel price changes are conducted as described in the previous sections.

The results of both scenarios are presented in Table 6.39-46. Besides, modal energy consumptions by fuel types are presented for these scenarios in Appendix A.

Table 6.39. Energy consumptions by fuel types in scenario 1.2.2 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	6.5	6.9	6.9	7.5	6.3	3.7	4.3	0.0
Diesel	322.6	389.4	349.6	378.2	421.4	427.5	288.2	265.5	87.9	54.7
Electricity	1.1	1.4	6.4	14.0	23.5	34.1	50.0	64.2	76.5	87.9
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	167.6	321.6
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	99.2	138.0	187.0	257.3
Jet Fuel	15.2	22.3	65.0	82.3	90.0	121.6	136.9	183.0	65.2	0.0
LPG	54.6	97.5	103.7	116.8	134.7	127.6	153.7	174.3	214.0	289.7
Gasoline	110.2	90.0	101.7	124.2	141.2	140.8	146.7	172.5	194.9	207.3
Ethanol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	173.4	173.4
Total	503.8	604.0	632.9	722.4	817.6	859.1	880.9	1016.1	1170.8	1391.8

Table 6.40. Share of fuel types in the total energy consumptions in scenario 1.2.2 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	1.0	1.0	0.8	0.9	0.7	0.4	0.4	0.0
Diesel	64.0	64.5	55.2	52.4	51.5	49.8	32.7	26.1	7.5	3.9
Electricity	0.2	0.2	1.0	1.9	2.9	4.0	5.7	6.3	6.5	6.3
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3	23.1
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	11.3	13.6	16.0	18.5
Jet Fuel	3.0	3.7	10.3	11.4	11.0	14.2	15.5	18.0	5.6	0.0
LPG	10.8	16.1	16.4	16.2	16.5	14.9	17.4	17.2	18.3	20.8
Gasoline	21.9	14.9	16.1	17.2	17.3	16.4	16.6	17.0	16.6	14.9
Ethanol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	14.8	12.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.41. Energy consumptions by fuel types in scenario 1.2.3 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	41.0	88.1	138.5	196.4	6.3	3.7	4.3	0.0
Diesel	322.6	389.4	324.7	324.1	334.7	208.7	195.3	187.4	42.6	54.7
Electricity	1.1	1.4	6.4	14.0	23.5	34.1	59.6	77.8	88.0	88.0
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.5	245.5	321.6
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	99.2	138.0	189.9	275.5
Jet Fuel	15.2	22.3	65.0	82.3	90.0	121.6	136.9	138.6	0.0	0.0
LPG	54.6	97.5	103.7	116.8	134.7	127.6	129.7	150.3	190.0	224.2
Gasoline	110.2	90.0	101.7	124.2	141.2	140.8	140.7	159.2	181.6	241.3
Ethanol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	0.0	0.0	93.4	93.4	93.4	218.7	173.4
Total	503.8	604.0	642.5	749.5	862.5	922.7	861.0	996.8	1160.6	1378.6

Table 6.42. Share of fuel types in the total energy consumptions in scenario 1.2.3 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	6.4	11.8	16.1	21.3	0.7	0.4	0.4	0.0
Diesel	64.0	64.5	50.5	43.2	38.8	22.6	22.7	18.8	3.7	4.0
Electricity	0.2	0.2	1.0	1.9	2.7	3.7	6.9	7.8	7.6	6.4
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	21.2	23.3
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	11.5	13.8	16.4	20.0
Jet Fuel	3.0	3.7	10.1	11.0	10.4	13.2	15.9	13.9	0.0	0.0
LPG	10.8	16.1	16.1	15.6	15.6	13.8	15.1	15.1	16.4	16.3
Gasoline	21.9	14.9	15.8	16.6	16.4	15.3	16.3	16.0	15.6	17.5
Ethanol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	0.0	0.0	10.1	10.9	9.4	18.8	12.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

In scenario 1.2.2, diesel consumptions decrease compared to the base scenario. Part of this decrease is due to the savings from the 10% modal shift realized in both freight and passenger transport. Besides, total diesel consumptions are further reduced by the 15% improved auto efficiencies (which means lower consumption a specific demand) and intensive use of bio-diesel (due to the increase in diesel fuel prices). In fact, as explained in the scenario 1.2.1 and 1.3.1, with the increased freight transport demand in railway and maritime sectors (shifted from road transport vehicles like trucks etc.) and passenger transport demand in intracity buses, diesel consumptions increase in these sectors. But, since the saved diesel fuel is considerably more than that increase, total diesel consumptions decrease in this scenario.

Gasoline and LPG consumptions decrease throughout the planning horizon, due to the reduced travel demand (caused by the 10 modal shift) in private cars and improved vehicle efficiencies. Additionally, one of the reasons for reduced gasoline and LPG consumptions is the limited introduction of electric powered TC1 vehicles between 2036 and 2051 (due to the 20% increase in fuel prices).

Compared with the base scenario, although intracity buses use hydrogen in 2051, gaseous hydrogen consumptions slightly decrease due to the reduced travel demand in heavy trucks and tractor trailers (that use gaseous hydrogen between 2036 and 2051) in this scenario. Besides, electricity consumptions increase mostly due to the increased demand values in intracity buses, metros, high-speed passenger and freight trains caused by the 10% modal shift realized in urban passenger transport and intercity freight transport. Likewise, CNG consumptions increase in intracity buses due to the mentioned modal shift. Lastly, since the demand for air transport increases with the modal shift from passenger cars and intercity buses, jet fuel consumptions and liquefied hydrogen consumptions also increase throughout the planning horizon.

In scenario 1.2.3, the energy consumption trends are similar to the trends discussed in scenario 1.2.2. But, in scenario 1.2.3, since the efficiency improvement and fuel price increase rates are 30%-40%, diesel and LPG consumptions are even lower, whereas electricity and bio-diesel consumptions are higher than scenario 1.2.2. Since the demand for air transport is the same in these two scenarios, only liquefied hydrogen consumption increases in the last 10 years due to the increased jet fuel prices. Besides, different from scenario 1.2.2, due to the increased diesel fuel prices, CNG fueled heavy trucks and tractor trailers are introduced to the market between 2016 and 2031 leading to much lower diesel consumption in those years.

Table 6.43. CO_2 emissions by fuel types in scenario 1.2.2 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	365	386	386	419	353	206	244	0
Diesel	23908	28852	25905	28024	31223	31677	21357	19672	6513	4052
Jet Fuel	1055	1542	4505	5700	6239	8430	9484	12681	4519	0
LPG	3443	6151	6542	7373	8498	8051	9698	10999	13502	18281
Gasoline	7716	6303	7117	8696	9882	9853	10266	12074	13641	14513
L. Hydrogen	0	0	0	0	0	0	0	0	8644	16579
Total	36121	43043	44435	50180	56229	58430	51157	55631	47064	53425

Table 6.44. Share of fuel types in the total CO_2 emissions in scenario 1.2.2 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	0.8	0.8	0.7	0.7	0.7	0.4	0.5	0.0
Diesel	66.2	67.0	58.3	55.8	55.5	54.2	41.7	35.4	13.8	7.6
Jet Fuel	2.9	3.6	10.1	11.4	11.1	14.4	18.5	22.8	9.6	0.0
LPG	9.5	14.3	14.7	14.7	15.1	13.8	19.0	19.8	28.7	34.2
Gasoline	21.4	14.6	16.0	17.3	17.6	16.9	20.1	21.7	29.0	27.2
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.4	31.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.45. CO_2 emissions by fuel types in scenario 1.2.3 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	2300	4944	7767	11021	353	206	244	0
Diesel	23908	28852	24061	24014	24801	15465	14474	13884	3156	4052
Jet Fuel	1055	1542	4505	5700	6239	8430	9484	9603	0	0
LPG	3443	6151	6542	7373	8498	8051	8183	9484	11988	14150
Gasoline	7716	6303	7117	8696	9882	9853	9845	11146	12713	16892
L. Hydrogen	0	0	0	0	0	0	0	2500	12660	16579
Total	36121	43043	44526	50728	57188	52820	42338	46823	40761	51673

Table 6.46. Share of fuel types in the total CO_2 emissions in scenario 1.2.3 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	5.2	9.7	13.6	20.9	0.8	0.4	0.6	0.0
Diesel	66.2	67.0	54.0	47.3	43.4	29.3	34.2	29.7	7.7	7.8
Jet Fuel	2.9	3.6	10.1	11.2	10.9	16.0	22.4	20.5	0.0	0.0
LPG	9.5	14.3	14.7	14.5	14.9	15.2	19.3	20.3	29.4	27.4
Gasoline	21.4	14.6	16.0	17.1	17.3	18.7	23.3	23.8	31.2	32.7
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3	31.1	32.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

When CO_2 emissions of these scenarios are analyzed, the domination of the impacts of efficiency improvement and price changes are immediately noticed for the years 2031-2051. In other words, scenarios 1.2.2 and 1.2.3 follow a very similar trend with scenarios 1.1.2 and 1.1.3 in those years. In both scenarios, the emissions are realized lower than the emissions in the base scenario. But, similar to the energy consumption values, CO_2 emissions values are lower in scenario 1.2.3 compared to scenario 1.2.2.

Regarding fuel types, in both scenarios 1.2.2 and 1.2.3, CO_2 emissions from diesel consumption are lower than the base scenario. The reason is the reduced diesel consumption due to the reduced travel demand from the 10% modal shift and increased bio-diesel and CNG consumptions used as alternative to diesel fuel (caused by the increased diesel fuel prices).

Emissions from gasoline and LPG decrease throughout the planning horizon, due to the reduced energy consumption caused by the reduced travel demand in private cars and increased vehicle efficiencies. Additionally, one of the reasons for reduced emissions from gasoline and LGP is the introduction of electric powered TC1 vehicles (although it has a limited impact) between 2036 and 2051.

Lastly, due to the increased demand in passenger air transport, jet fuel consumptions are higher in scenarios 1.2.3 and 1.2.3 compared with the base scenario. But, the emissions from air transport in scenario 1.2.3 are lower than scenario 1.2.2 due to the increased hydrogen use in the sector.

The mentioned CO_2 emission trends can be seen in Figure 6.8 and 6.9. In scenario 1.2.2, the drop between 2031 and 2036 stem from the sharp decrease in emissions from diesel fuel due to the introduction of gaseous hydrogen use in heavy trucks and tractor trailers, whereas the drop between 2041 and 2046 stem from the increase in bio-diesel consumptions. Likewise, in scenario 1.2.3, the drop between 2026 and 2036 is caused by the introduction of CNG and hydrogen fueled heavy trucks and tractor trailer, whereas, the drop between 2041 and 2046 is caused by intensive use of bio-diesel.

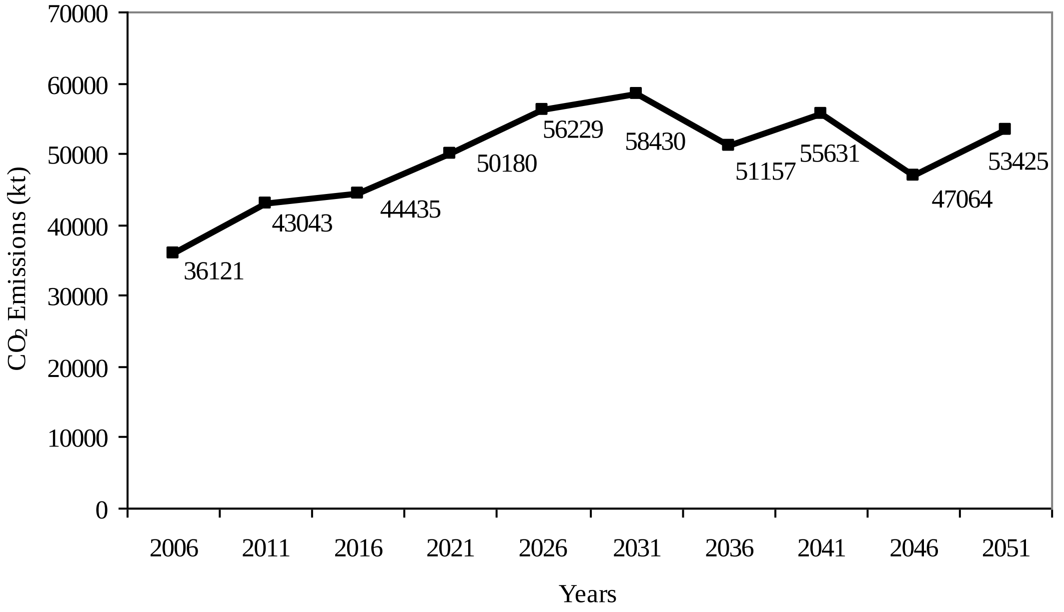

Figure 6.8. CO_2 emissions of the transport sector in scenario 1.2.2.

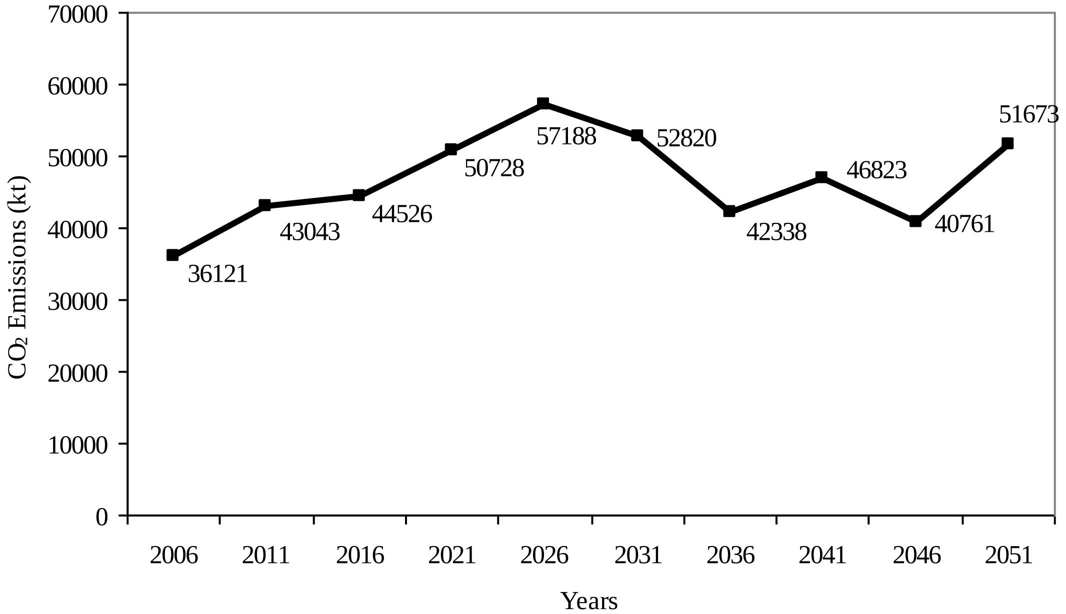

Figure 6.9. CO_2 emissions of the transport sector in scenario 1.2.3.

6.4.2. The 15-30% Efficiency Improvement and 20-40% Fuel Price Increase Scenarios with the 20% Modal Shift Scenario (1.3.2 and 1.3.3)

The 15%-30% and the 20%-40% efficiency improvement and fuel price increase scenarios are integrated with the 20% modal shift scenario to generate the dual change scenarios 1.3.2 and 1.3.3. The modal shift, efficiency improvement and fuel price changes are conducted as described in the previous sections.

The results of both scenarios are presented in Table 6.47-54. Besides, modal energy consumptions by fuel types are presented for these scenarios in Appendix A.

Table 6.47. Energy consumptions by fuel types in scenario 1.3.2 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	7.2	7.6	7.6	8.1	6.8	3.9	4.6	0.0
Diesel	322.64	389.37	330.92	357.98	397.17	401.14	277.85	270.42	90.55	65.63
Electricity	1.1	1.4	7.9	16.7	27.9	40.6	57.3	74.6	83.6	83.6
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	206.6	369.7
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	88.2	122.7	173.7	256.1
Jet Fuel	15.2	22.3	97.2	114.9	118.7	149.2	165.6	211.7	67.2	0.0
LPG	54.6	97.5	98.2	110.0	125.8	113.7	137.0	155.3	190.3	259.6
Gasoline	110.2	90.0	89.8	109.8	124.9	123.2	132.2	155.2	175.1	184.0
Ethanol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bio-Diesel	0	0	0	0	0	0	0	0	166.08	166.08
Total	503.8	604.0	631.2	716.9	802.0	835.9	865.0	993.7	1157.6	1384.8

Table 6.48. Share of fuel types in the total energy consumptions in scenario 1.3.2 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	1.1	1.1	0.9	1.0	0.8	0.4	0.4	0.0
Diesel	64.0	64.5	52.4	49.9	49.5	48.0	32.1	27.2	7.8	4.7
Electricity	0.2	0.2	1.3	2.3	3.5	4.9	6.6	7.5	7.2	6.0
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.8	26.7
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	10.2	12.3	15.0	18.5
Jet Fuel	3.0	3.7	15.4	16.0	14.8	17.8	19.1	21.3	5.8	0.0
LPG	10.8	16.1	15.6	15.3	15.7	13.6	15.8	15.6	16.4	18.7
Gasoline	21.9	14.9	14.2	15.3	15.6	14.7	15.3	15.6	15.1	13.3
Ethanol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3	12.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.49. Energy consumptions by fuel types in scenario 1.3.3 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	37.8	79.8	124.1	175.7	6.8	3.9	4.6	0.0
Diesel	322.64	389.37	308.79	310.2	320.34	248.82	237.24	229.59	51.52	65.63
Electricity	1.1	1.4	7.9	16.7	27.9	40.6	64.0	81.3	83.6	83.6
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51.8	286.8	369.7
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	88.2	122.7	182.7	265.1
Jet Fuel	15.2	22.3	96.8	114.5	118.7	149.2	165.6	169.4	0.0	0.0
LPG	54.6	97.5	98.2	110.0	125.8	113.7	119.1	137.3	172.4	202.6
Gasoline	110.2	90.0	89.8	109.8	124.9	123.2	129.2	153.1	173.0	226.5
Ethanol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bio-Diesel	0	0	0	0	0	41.06	41.06	41.06	205.11	166.08
Total	503.8	604.0	639.3	740.9	841.7	892.3	851.2	990.2	1159.7	1379.2

Table 6.50. Share of fuel types in the total energy consumptions in scenario 1.3.3 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	5.9	10.8	14.7	19.7	0.8	0.4	0.4	0.0
Diesel	64.0	64.5	48.3	41.9	38.1	27.9	27.9	23.2	4.4	4.8
Electricity	0.2	0.2	1.2	2.2	3.3	4.6	7.5	8.2	7.2	6.1
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.2	24.7	26.8
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	10.4	12.4	15.8	19.2
Jet Fuel	3.0	3.7	15.1	15.4	14.1	16.7	19.5	17.1	0.0	0.0
LPG	10.8	16.1	15.4	14.8	14.9	12.7	14.0	13.9	14.9	14.7
Gasoline	21.9	14.9	14.0	14.8	14.8	13.8	15.2	15.5	14.9	16.4
Ethanol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	0.0	0.0	4.6	4.8	4.1	17.7	12.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

In scenario 1.3.2, diesel consumptions decrease compared to the base scenario. This decrease is based on the savings from the 20% modal shift realized in both freight and passenger transport. Besides, total diesel consumptions are reduced as a result of the 15% improvement in auto efficiencies (which means lower consumption a specific demand) and intensive use of bio-diesel (due to the 20% increase in diesel fuel prices) especially in the last 10 years of the planning horizon. In fact, as explained in scenarios 1.2.1 and 1.3.1, with the increased freight transport demand in railway and maritime sectors (shifted from road transport vehicles like trucks etc.) and passenger transport demand in intracity buses, diesel consumptions increase in these sectors. But, since the saved diesel energy is more than that increase, total diesel consumptions decrease in this scenario.

Gasoline and LPG consumptions decrease throughout the planning horizon, due to the reduced travel demand (caused by the 20% modal shift) in private cars and improved vehicle efficiencies. Another reason for reduced gasoline and LPG consumptions is the introduction of electric powered TC1 vehicles between 2036 and 2051 (due to the 20% increase in fuel prices).

Compared with the base scenario, although intracity buses use hydrogen in 2046 and 2051, total gaseous hydrogen consumption slightly decreases in this scenario, due to the reduced travel demand in heavy trucks and tractor trailers (that use gaseous hydrogen between 2036 and 2051). Besides, electricity consumptions increase mostly due to the increased demand values in intracity buses, metros, high-speed passenger and freight trains caused by the 20% modal shift realized in urban passenger transport and intercity freight transport. Likewise, CNG consumptions of intracity buses increase due to the increase in demand values by the mentioned 20% modal shift. Lastly, since the demand for air transport increases with the modal shift from passenger cars and intercity buses, jet fuel consumptions and liquefied hydrogen consumptions are also increased.

In scenario 1.3.3, the energy consumption trends are similar with the trends in scenario 1.3.2. But, compared with scenario 1.3.2, since the efficiency improvement and fuel prices rates are higher (30%-40%) in scenario 1.3.3, diesel and LPG consumptions are lower, whereas electricity and bio-diesel consumptions are higher. Since the demand for air transport is the same in these two scenarios, only liquefied hydrogen consumptions increase in the last 10 years due to the increased jet fuel prices. Besides, different from scenario 1.3.2, due to the increased diesel fuel prices, CNG fueled heavy trucks and tractor trailers are introduced to the market between 2016 and 2031, leading to lower diesel consumptions in those years.

Table 6.51. CO_2 emissions by fuel types in scenario 1.3.2 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	401	425	425	454	380	221	260	0
Diesel	23908	28852	24521	26526	29430	29725	20588	20038	6710	4863
Jet Fuel	1055	1542	6739	7963	8222	10339	11478	14667	4653	0
LPG	3443	6151	6197	6941	7938	7171	8647	9796	12005	16382
Gasoline	7716	6303	6284	7683	8739	8625	9251	10863	12254	12878
L. Hydrogen	0	0	0	0	0	0	0	0	10652	19064
Total	36121	43043	44141	49539	54755	56313	50345	55585	46535	53187

Table 6.52. Share of fuel types in the total CO_2 emissions in scenario 1.3.2 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	0.9	0.9	0.8	0.8	0.8	0.4	0.6	0.0
Diesel	66.2	67.0	55.6	53.5	53.7	52.8	40.9	36.0	14.4	9.1
Jet Fuel	2.9	3.6	15.3	16.1	15.0	18.4	22.8	26.4	10.0	0.0
LPG	9.5	14.3	14.0	14.0	14.5	12.7	17.2	17.6	25.8	30.8
Gasoline	21.4	14.6	14.2	15.5	16.0	15.3	18.4	19.5	26.3	24.2
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.9	35.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.53. CO_2 emissions by fuel types in scenario 1.3.3 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	2122	4477	6964	9856	380	221	260	0
Diesel	23908	28852	22881	22986	23737	18437	17579	17013	3818	4863
Jet Fuel	1055	1542	6707	7931	8222	10339	11478	11740	0	0
LPG	3443	6151	6197	6941	7938	7171	7517	8666	10875	12781
Gasoline	7716	6303	6284	7683	8739	8625	9039	10718	12109	15856
L. Hydrogen	0	0	0	0	0	0	0	2670	14788	19064
Total	36121	43043	44190	50018	55601	54428	45994	51028	41850	52564

Table 6.54. Share of fuel types in the total CO_2 emissions in scenario 1.3.3 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	4.8	9.0	12.5	18.1	0.8	0.4	0.6	0.0
Diesel	66.2	67.0	51.8	46.0	42.7	33.9	38.2	33.3	9.1	9.3
Jet Fuel	2.9	3.6	15.2	15.9	14.8	19.0	25.0	23.0	0.0	0.0
LPG	9.5	14.3	14.0	13.9	14.3	13.2	16.3	17.0	26.0	24.3
Gasoline	21.4	14.6	14.2	15.4	15.7	15.8	19.7	21.0	28.9	30.2
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.2	35.3	36.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

When CO_2 emissions of these scenarios are analyzed, the domination of the impacts of efficiency improvement and price changes are immediately noticed for the years 2031-2051. In other words, scenarios 1.3.2 and 1.3.3 follow a similar trend with scenarios 1.1.2 and 1.1.3 in those years (but with larger fluctuations caused by 20% modal shift). In both scenarios, the emissions are lower than the emissions in the base scenario. But, similar to the energy consumption values, CO_2 emissions values are lower in scenario 1.3.3 compared to scenario 1.3.2.

Regarding fuel types, in both scenarios 1.3.2 and 1.3.3, CO_2 emissions from diesel consumption are lower than the base scenario. The reason for this decrease is based on the reduced diesel consumptions due to the reduced travel demand from the 20% modal shift and the increased bio-diesel (both in scenarios 1.3.2 and 1.3.3) and CNG (mostly in scenario 1.3.3) consumptions as alternative to conventional diesel fuel (caused by the increased diesel fuel prices).

Emissions from LPG and gasoline decrease in the last 20 years, due to the reduced energy consumptions caused by the reduced travel demand in private cars and increased vehicle efficiencies. Additionally, one of the reasons for reduced emissions from gasoline and LPG is the introduction of electric powered TC1 vehicles (although it has a limited impact) between 2036 and 2051.

Lastly, due to the increased demand in passenger air transport, jet fuel consumptions are higher in scenarios 1.3.2 and 1.3.3 compared with the base scenario. But, the emissions from air transport in scenario 1.3.3 are lower than the level in scenario 1.3.2 due to the increased hydrogen usage in the sector.

The mentioned CO_2 emission trends can be seen in Figure 6.10 and 6.11. In scenario 1.3.2, the drop between 2031 and 2036 stem from the sharp decrease in emissions from diesel fuel due to the introduction of gaseous hydrogen use in heavy trucks and tractor trailers, whereas the drop between 2041 and 2046 stem from the increase in bio-diesel consumptions. Likewise, in scenario 1.3.3, the drop between 2026 and 2036 is caused by the introduction of bio-diesel instead of conventional diesel and CNG and hydrogen fueled heavy trucks and tractor trailer, whereas, the drop between 2041 and 2046 is caused by much more intensive use of bio-diesel.

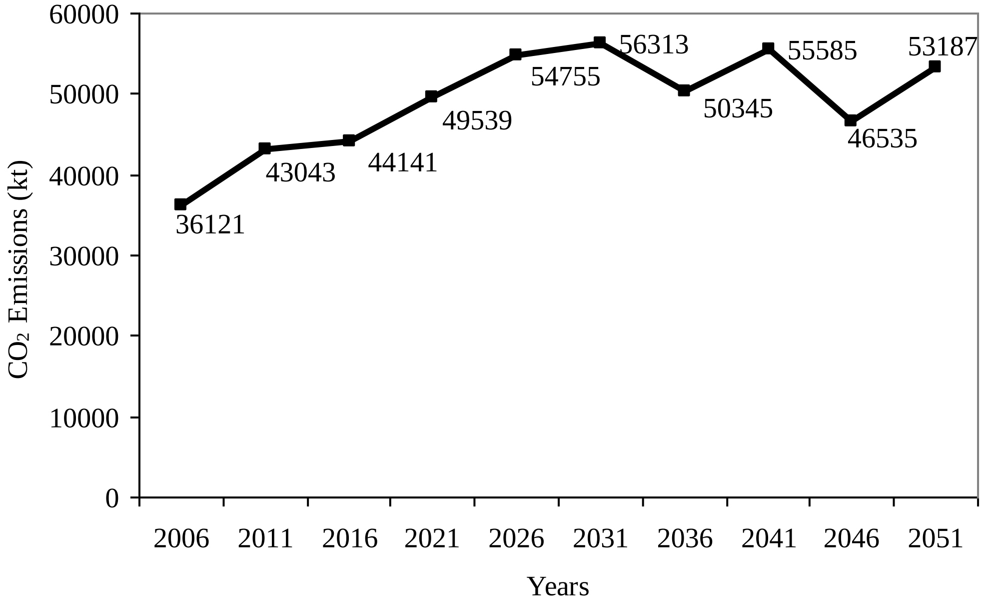

Figure 6.10. CO_2 emissions of the transport sector in scenario 1.3.2.

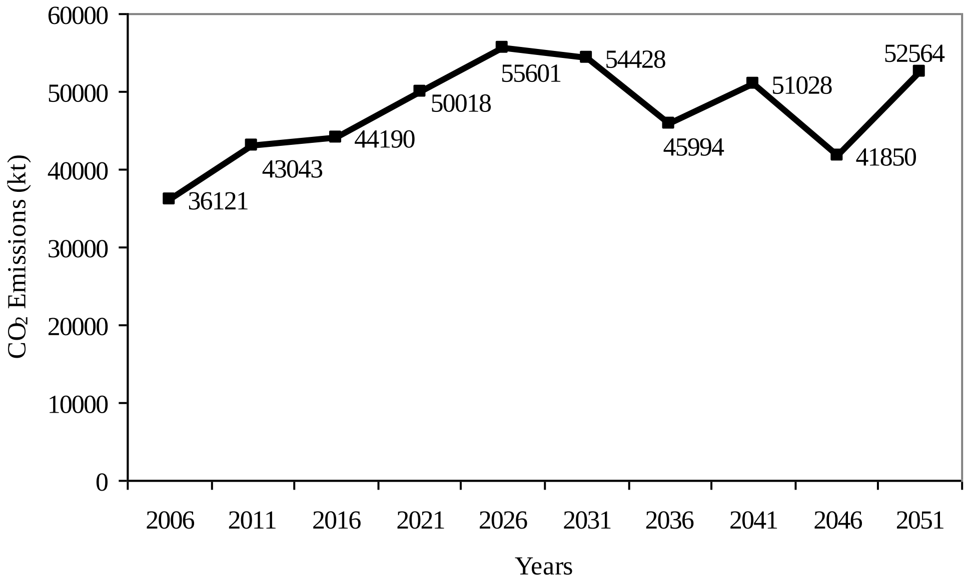

Figure 6.11. CO_2 emissions of the transport sector in scenario 1.3.3.

6.4.3. The 15% and the 30% Emission Reduction Scenarios with the 15% Efficiency Improvement and 20% Fuel Price Increase Scenario (2.1.2 and 3.1.2)

The 15% and the 30% emission reduction scenarios are integrated with the 15 % efficiency improvement and the 20% fuel price increase to generate the dual change scenarios 2.1.2 and 3.1.2. The emission constraints, efficiency improvement and the fuel price changes are conducted as described in the previous sections.

The results of both scenarios are presented in Table 6.55-62. Besides, modal energy consumptions by fuel types are presented for these scenarios in Appendix A.

Table 6.55. Energy consumptions by fuel types in scenario 2.1.2 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	5.4	6.4	6.4	6.5	5.9	3.5	3.8	0.0
Diesel	322.6	389.4	364.3	341.9	390.1	398.6	243.9	215.9	33.7	43.7
Electricity	1.1	1.4	4.9	11.3	19.0	27.7	42.1	53.2	63.3	74.9
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	173.7	273.4
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	110.2	153.3	207.8	281.2
Jet Fuel	15.2	22.3	32.2	49.1	61.4	94.0	108.1	148.9	25.6	0.0
LPG	54.6	97.5	111.3	126.4	146.3	141.7	170.3	192.9	237.1	321.8
Gasoline	110.2	85.1	33.5	94.4	102.4	122.2	89.7	119.0	216.4	230.7
Ethanol	0.0	0.0	72.5	36.1	46.9	34.8	72.5	72.5	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	55.0	55.0	55.0	55.0	74.8	232.3	180.8
Total	503.8	599.1	624.1	720.6	827.6	880.5	897.8	1034.0	1193.7	1406.3

Table 6.56. Share of fuel types in the total energy consumptions in scenario 2.1.2 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	0.9	0.9	0.8	0.7	0.7	0.3	0.3	0.0
Diesel	64.0	65.0	58.4	47.5	47.1	45.3	27.2	20.9	2.8	3.1
Electricity	0.2	0.2	0.8	1.6	2.3	3.1	4.7	5.1	5.3	5.3
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.6	19.4
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	12.3	14.8	17.4	20.0
Jet Fuel	3.0	3.7	5.2	6.8	7.4	10.7	12.0	14.4	2.1	0.0
LPG	10.8	16.3	17.8	17.5	17.7	16.1	19.0	18.7	19.9	22.9
Gasoline	21.9	14.2	5.4	13.1	12.4	13.9	10.0	11.5	18.1	16.4
Ethanol	0.0	0.0	11.6	5.0	5.7	3.9	8.1	7.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	7.6	6.6	6.2	6.1	7.2	19.5	12.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.57. Energy consumptions by fuel types in scenario 3.1.2 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	5.4	6.4	6.4	6.5	5.9	3.5	3.8	0.0
Diesel	322.6	388.2	358.5	244.9	286.8	297.2	155.7	184.6	33.7	43.7
Electricity	1.1	1.4	6.7	13.1	20.8	29.5	42.1	53.2	63.3	74.9
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	173.7	273.4
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	110.2	153.3	207.8	281.2
Jet Fuel	15.2	22.3	32.2	49.1	61.4	94.0	108.1	144.6	25.6	0.0
LPG	54.6	97.5	93.4	135.9	146.4	136.7	168.6	192.6	237.8	328.8
Gasoline	110.2	85.1	0.0	78.4	85.9	98.1	81.5	109.9	215.9	216.7
Ethanol	0.0	0.0	107.3	36.1	56.6	56.4	77.1	82.0	0.0	9.1
Bio-Diesel	0.0	0.0	0.0	147.9	156.6	156.6	143.3	106.2	231.5	180.1
Total	503.8	597.9	603.6	711.8	820.9	875.1	892.5	1030.0	1193.1	1407.7

Table 6.58. Share of fuel types in the total energy consumptions in scenario 3.1.2 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	0.9	0.9	0.8	0.7	0.7	0.3	0.3	0.0
Diesel	64.0	64.9	59.4	34.4	34.9	34.0	17.4	17.9	2.8	3.1
Electricity	0.2	0.2	1.1	1.8	2.5	3.4	4.7	5.2	5.3	5.3
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.6	19.4
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	12.3	14.9	17.4	20.0
Jet Fuel	3.0	3.7	5.3	6.9	7.5	10.7	12.1	14.0	2.1	0.0
LPG	10.8	16.3	15.5	19.1	17.8	15.6	18.9	18.7	19.9	23.4
Gasoline	21.9	14.2	0.0	11.0	10.5	11.2	9.1	10.7	18.1	15.4
Ethanol	0.0	0.0	17.8	5.1	6.9	6.4	8.6	8.0	0.0	0.6
Bio-Diesel	0.0	0.0	0.0	20.8	19.1	17.9	16.1	10.3	19.4	12.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

In scenarios 2.1.2 and 3.1.2, total diesel consumptions decrease compared with the base scenario. This decrease is based on the added 15% and 30% emissions constraints and increased fuel prices together. With the emission constraints, the bio-diesel consumption is deployed after 2021. Besides, with the 15% improved auto efficiencies, the diesel consumption of private cars are reduced. In addition, (although limited) CNG is used in heavy trucks and the total CNG consumptions increase slightly in these scenarios compared with the base scenario.

Regarding gasoline consumptions, due to the added CO_2 constraints, ethanol is deployed for gasoline fueled private cars between 2016 and 2041. In scenario 2.1.2, after 2041, gasoline consumption increases again (since its cost is less than ethanol's) due to already satisfied emission constraint by other fuel types in the last 10 years. But, in scenario, 3.1.2, since the emissions tend to realize over the emission bound in 2051, ethanol is also consumed in 2051 again. In addition to gasoline consumptions, LPG consumptions also decrease from the base scenario to scenarios 2.1.2 and 3.1.2; due to 15% improved fuel efficiencies in LPG fueled vehicles. Besides, it is seen that fuel price increase does not significantly effect the technology selection in private cars. The only difference is the introduction of electric powered TC1 cars in scenario 2.1.2 and TC1 and TC2 cars in scenario 3.1.2.

Electricity (except for TC1 and TC2) and gaseous hydrogen consumptions do not change in these scenarios, because they are already non-CO_2 emitting fuel types and the demand values for the vehicles using such fuel types are not changed in these scenarios. Lastly, due to the 15% and the 30% CO_2 emission reduction constraints, jet fuel consumptions decrease and the liquefied hydrogen consumption (which is a cleaner fuel than jet fuel) increases in these scenarios.

Table 6.59. CO_2 emissions by fuel types in scenario 2.1.2 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	303	357	357	366	333	196	212	0
Diesel	23908	28852	26992	25336	28909	29537	18072	15996	2495	3241
Jet Fuel	1055	1542	2234	3400	4257	6517	7489	10319	1775	0
LPG	3443	6151	7023	7977	9234	8943	10746	12169	14964	20304
Gasoline	7716	5960	2343	6605	7171	8550	6280	8328	15146	16147
L. Hydrogen	0	0	0	0	0	0	0	0	8955	14095
Total	36121	42699	38895	43675	49927	53913	42920	47008	43546	53787

Table 6.60. Share of fuel types in the total CO_2 emissions in scenario 2.1.2 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	0.8	0.8	0.7	0.7	0.8	0.4	0.5	0.0
Diesel	66.2	67.6	69.4	58.0	57.9	54.8	42.1	34.0	5.7	6.0
Jet Fuel	2.9	3.6	5.7	7.8	8.5	12.1	17.4	22.0	4.1	0.0
LPG	9.5	14.4	18.1	18.3	18.5	16.6	25.0	25.9	34.4	37.7
Gasoline	21.4	14.0	6.0	15.1	14.4	15.9	14.6	17.7	34.8	30.0
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.6	26.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.61. CO_2 emissions by fuel types in scenario 3.1.2 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	303	357	357	366	333	196	212	0
Diesel	23908	28765	26568	18146	21248	22023	11537	13676	2495	3241
Jet Fuel	1055	1542	2234	3400	4257	6517	7489	10021	1775	0
LPG	3443	6151	5894	8577	9241	8625	10637	12155	15008	20746
Gasoline	7716	5960	0	5488	6014	6867	5705	7693	15115	15166
L. Hydrogen	0	0	0	0	0	0	0	0	8955	14095
Total	36121	42613	35000	35967	41116	44399	35701	43741	43560	53247

Table 6.62. Share of fuel types in the total CO_2 emissions in scenario 3.1.2 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	0.9	1.0	0.9	0.8	0.9	0.4	0.5	0.0
Diesel	66.2	67.5	75.9	50.5	51.7	49.6	32.3	31.3	5.7	6.1
Jet Fuel	2.9	3.6	6.4	9.5	10.4	14.7	21.0	22.9	4.1	0.0
LPG	9.5	14.4	16.8	23.8	22.5	19.4	29.8	27.8	34.5	39.0
Gasoline	21.4	14.0	0.0	15.3	14.6	15.5	16.0	17.6	34.7	28.5
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.6	26.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

When CO_2 emissions of these scenarios are analyzed, it is seen that the total emissions realize lower than the base scenario due to the applied 15% and 30% emission reduction scenario (especially between 2011 and 2031) and also the 15% efficiency improvement (especially between 2036 and 2051).

Regarding fuel types, in both scenarios 2.1.2 and 3.1.2, CO_2 emissions from diesel consumption are lower than the base scenario. The reason for is the deployment of bio-diesel instead of conventional diesel fuel and also reduced diesel consumptions in private cars. Likewise, emissions from LPG consumption are also decreased due to the increased efficiencies in LPG fueled private cars. As explained in the energy consumption part, gasoline consumptions are also decreased due to ethanol consumption (between 2016 and 2041) in private cars. But, ethanol consumption decreases in the last 10 years of the planning horizon. Thus, the emissions from gasoline consumption increase in 2046 and 2051 in both scenarios.

CO_2 emissions resulting from CNG consumption slightly increases due to the introduction of CNG fueled heavy trucks in 2026 and 2031. Lastly, due to the 15% and 30% CO_2 emissions reduction scenarios, emissions resulting from jet fuel decreases whereas emissions from liquefied hydrogen increases in both scenarios (leading to lower emissions from air transport compared with the base scenario).

When the trend of CO_2 emissions (Figure 6.12 and 6.13) are analyzed, it is seen that, in scenario 2.1.2, the emissions drop in 2036 and 2041 are mostly due to sharply decreased diesel fuel consumption (caused by the introduction of gaseous hydrogen fueled TH1 and TH2 vehicles in 2036 and much more increased bio-diesel consumption in 2041). Likewise, in scenario 3.1.2, there is a sharp decrease in 2036 due to introduction of gaseous hydrogen fueled TH1 and TH2 vehicles.

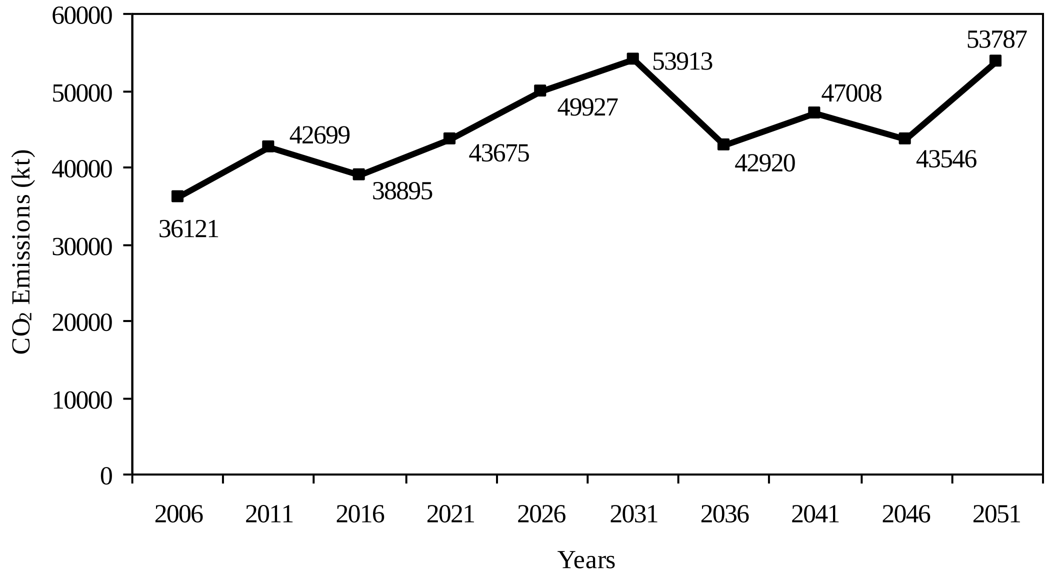

Figure 6.12. CO_2 emissions of the transport sector in scenario 2.1.2.

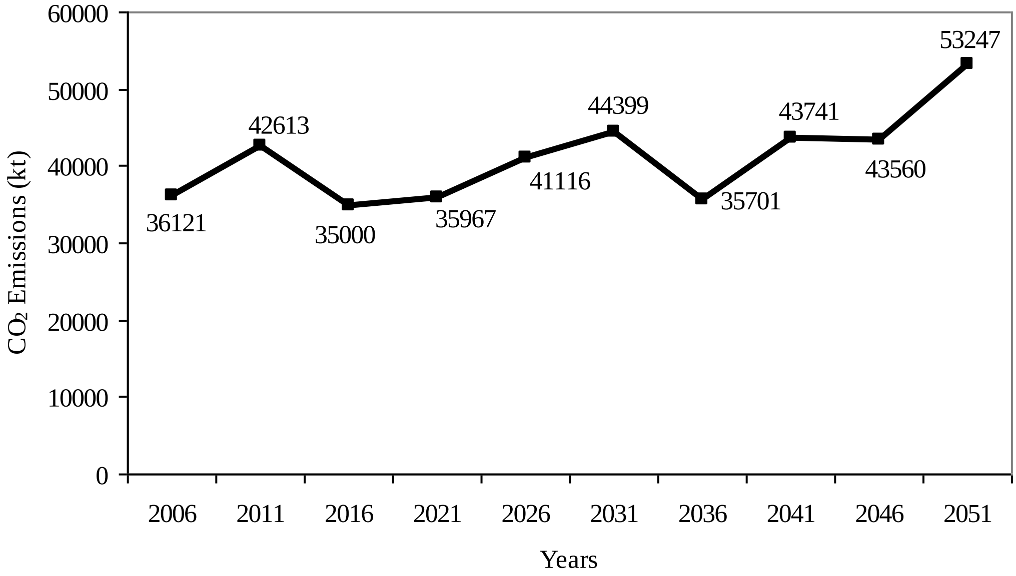

Figure 6.13. CO_2 emissions of the transport sector in scenario 3.1.2.

6.4.4. The 15% and the 30% Emission Reduction Scenarios with the 30% Efficiency Improvement and 40% Fuel Price Increase Scenario (2.1.3 and 3.1.3)

The 15% and the 30% emission reduction scenarios are integrated with the 15 % efficiency improvement and the 20% fuel price increase to generate the dual change scenarios 2.1.2 and 3.1.2. The emission constraints, efficiency improvement and the fuel price changes are conducted as described in the previous sections.

The results of both scenarios are presented in Table 6.63-70. Besides, modal energy consumptions by fuel types are presented for these scenarios in Appendix A.

Table 6.63. Energy consumptions by fuel types in scenario 2.1.3 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	43.7	96.6	152.9	216.9	5.9	3.5	3.8	0.0
Diesel	322.6	389.4	337.2	252.2	220.4	170.3	153.4	144.5	33.7	43.7
Electricity	1.1	1.4	4.9	11.3	19.0	27.7	42.0	59.6	69.6	81.2
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.8	204.3	273.4
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	110.2	153.3	207.8	281.2
Jet Fuel	15.2	22.3	32.2	49.1	61.4	94.0	108.1	108.1	0.0	0.0
LPG	54.6	97.5	110.2	123.2	140.7	126.0	151.0	171.2	242.9	317.7
Gasoline	110.2	85.1	32.4	119.9	88.1	73.7	76.5	87.9	157.9	169.6
Ethanol	0.0	0.0	71.2	6.9	56.6	69.2	71.2	71.2	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	83.9	127.1	140.7	140.7	140.7	227.3	177.1
Total	503.8	599.1	631.8	743.1	866.2	918.4	859.0	984.8	1147.2	1343.9

Table 6.64. Share of fuel types in the total energy consumptions in scenario 2.1.3 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	6.9	13.0	17.7	23.6	0.7	0.4	0.3	0.0
Diesel	64.0	65.0	53.4	33.9	25.4	18.5	17.9	14.7	2.9	3.3
Electricity	0.2	0.2	0.8	1.5	2.2	3.0	4.9	6.0	6.1	6.0
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	17.8	20.3
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	12.8	15.6	18.1	20.9
Jet Fuel	3.0	3.7	5.1	6.6	7.1	10.2	12.6	11.0	0.0	0.0
LPG	10.8	16.3	17.4	16.6	16.2	13.7	17.6	17.4	21.2	23.6
Gasoline	21.9	14.2	5.1	16.1	10.2	8.0	8.9	8.9	13.8	12.6
Ethanol	0.0	0.0	11.3	0.9	6.5	7.5	8.3	7.2	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	11.3	14.7	15.3	16.4	14.3	19.8	13.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.65. Energy consumptions by fuel types in scenario 3.1.3 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	5.4	81.8	152.0	201.9	5.9	3.5	3.8	0.0
Diesel	322.6	388.3	357.7	193.4	185.5	157.4	133.0	123.9	33.7	43.7
Electricity	1.1	1.4	6.7	13.1	20.8	29.5	42.1	58.7	68.8	80.4
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	17.2	62.0	204.3	273.4
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	110.2	153.3	207.8	281.2
Jet Fuel	15.2	22.3	32.2	49.1	61.4	94.0	94.1	94.1	0.0	0.0
LPG	54.6	97.5	94.4	126.2	139.9	121.1	150.1	168.3	240.3	320.3
Gasoline	110.2	85.1	0.0	81.2	82.3	72.0	67.2	81.4	161.9	169.4
Ethanol	0.0	0.0	105.4	36.1	56.6	69.2	77.1	82.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	148.0	161.8	161.8	161.8	161.8	226.4	176.4
Total	503.8	598.0	601.8	728.9	860.3	907.0	858.7	989.0	1146.9	1344.8

Table 6.66. Share of fuel types in the total energy consumptions in scenario 3.1.3 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	0.9	11.2	17.7	22.3	0.7	0.4	0.3	0.0
Diesel	64.0	64.9	59.4	26.5	21.6	17.4	15.5	12.5	2.9	3.3
Electricity	0.2	0.2	1.1	1.8	2.4	3.2	4.9	5.9	6.0	6.0
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	2.0	6.3	17.8	20.3
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	12.8	15.5	18.1	20.9
Jet Fuel	3.0	3.7	5.4	6.7	7.1	10.4	11.0	9.5	0.0	0.0
LPG	10.8	16.3	15.7	17.3	16.3	13.4	17.5	17.0	21.0	23.8
Gasoline	21.9	14.2	0.0	11.1	9.6	7.9	7.8	8.2	14.1	12.6
Ethanol	0.0	0.0	17.5	5.0	6.6	7.6	9.0	8.3	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	20.3	18.8	17.8	18.8	16.4	19.7	13.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

In scenarios 2.1.3 and 3.1.3, total diesel consumptions decrease compared with the base scenario. This decrease is based on the added 15% and 30% emissions constraints and 30% increased fuel prices together. With the emission constraints, bio-diesel is deployed after 2021. Besides, with the 30% improved auto efficiencies, the diesel consumption of private cars are reduced. In addition, CNG is intensively used in heavy trucks and tractor trailers (between 2016 and 2031 in scenario 2.1.3; between 2021 and 2031 in scenario 3.1.3) leading to lower diesel consumptions in such vehicles.

Regarding gasoline consumptions, due to the added 15% and 30% CO_2 emission constraints, ethanol is deployed for gasoline fueled private cars between 2016 and 2041. In scenario 2.1.3 and 3.1.3, after 2041, gasoline consumptions increase again (since it costs less than ethanol’s) due to already satisfied emission constraint by other fuel types in the last 10 years of the planning horizon. In addition to gasoline consumptions, LPG consumptions also decrease from base scenario to scenario 2.1.3 and 3.1.3; due to the 30%

improved fuel efficiencies in LPG fueled vehicles. Besides, it is seen that fuel price increase does not significantly effect the technology selection in private cars. The only difference is the introduction of electric powered TC1 cars in scenario 2.1.3 and TC1 and TC2 cars in scenario 3.1.3.

Electricity (except for TC1 and TC2) and gaseous hydrogen consumptions do not change in these scenarios, because they are already non-CO_2 emitting fuel types and the demand values for the vehicles using such fuel types are not changed in these scenarios. Lastly, due to the 15% and the 30% CO_2 emission reduction constraints, jet fuel consumptions decrease and the liquefied hydrogen consumptions (which is a cleaner fuel than jet fuel) increase in both scenarios compared with the base scenario.

Table 6.67. CO_2 emissions by fuel types in scenario 2.1.3 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	2453	5421	8579	12167	333	196	212	0
Diesel	23908	28852	24983	18685	16332	12618	11368	10709	2495	3241
Jet Fuel	1055	1542	2234	3400	4257	6517	7489	7489	0	0
LPG	3443	6151	6955	7774	8879	7948	9526	10802	15325	20048
Gasoline	7716	5960	2268	8394	6163	5156	5358	6154	11054	11872
L. Hydrogen	0	0	0	0	0	0	0	2310	10532	14095
Total	36121	42699	38895	43675	44210	44407	34073	37659	39618	49256

Table 6.68. Share of fuel types in the total CO_2 emissions in scenario 2.1.3 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	6.3	12.4	19.4	27.4	1.0	0.5	0.5	0.0
Diesel	66.2	67.6	64.2	42.8	36.9	28.4	33.4	28.4	6.3	6.6
Jet Fuel	2.9	3.6	5.7	7.8	9.6	14.7	22.0	19.9	0.0	0.0
LPG	9.5	14.4	17.9	17.8	20.1	17.9	28.0	28.7	38.7	40.7
Gasoline	21.4	14.0	5.8	19.2	13.9	11.6	15.7	16.3	27.9	24.1
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	26.6	28.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.69. CO_2 emissions by fuel types in scenario 3.1.3 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	303	4591	8525	11327	333	196	212	0
Diesel	23908	28773	26504	14331	13749	11665	9856	9182	2495	3241
Jet Fuel	1055	1542	2234	3400	4257	6517	6517	6517	0	0
LPG	3443	6151	5958	7963	8826	7644	9470	10618	15166	20213
Gasoline	7716	5960	0	5683	5760	5041	4702	5697	11331	11860
L. Hydrogen	0	0	0	0	0	0	886	3196	10532	14095
Total	36121	42620	35000	35967	41116	42194	31765	35406	39736	49409

Table 6.70. Share of fuel types in the total CO_2 emissions in scenario 3.1.3 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	0.9	12.8	20.7	26.8	1.0	0.6	0.5	0.0
Diesel	66.2	67.5	75.7	39.8	33.4	27.6	31.0	25.9	6.3	6.6
Jet Fuel	2.9	3.6	6.4	9.5	10.4	15.4	20.5	18.4	0.0	0.0
LPG	9.5	14.4	17.0	22.1	21.5	18.1	29.8	30.0	38.2	40.9
Gasoline	21.4	14.0	0.0	15.8	14.0	11.9	14.8	16.1	28.5	24.0
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	2.8	9.0	26.5	28.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

When CO_2 emissions of these scenarios are analyzed, it is seen that the total emissions realize lower than the base scenario due to the applied 15% and 30% emission reduction scenario (especially between 2011 and 2026) and also the 30% efficiency improvement and 40% fuel price increase (especially between 2031 and 2051).

Regarding fuel types, in both scenarios 2.1.3 and 3.1.3, CO_2 emissions from diesel consumption are lower than the base scenario. The reason is the deployment of bio-diesel instead of conventional diesel fuel (between 2021 and 2051) and intensive CNG consumption in heavy trucks and tractor trailers (which also leads to higher CO_2 emissions from CNG consumptions between 2016 and 2031 in scenario 2.1.3 and between 2021 and 2031 in scenario 3.1.3), and also reduced diesel consumptions in private cars throughout the planning horizon. Likewise, emissions from LPG consumption are also decreased due to the increased efficiencies in LPG fueled private cars.

As explained in the energy consumption part, gasoline consumptions are also decreased due to ethanol consumption (between 2016 and 2041) in private cars. In the last 10 years of the planning horizon, ethanol consumption decreases, and therefore, the emissions resulting from gasoline consumptions increase between 2046 and 2051 in both scenarios.

Lastly, due to the 15% and 30% CO_2 emissions reduction scenarios, emissions resulting from jet fuel consumption decreases, whereas emissions from liquefied hydrogen increases in both scenarios (leading to lower emissions from air transport compared with the base scenario). When the trend of CO_2 emissions (Figure 6.14 and 6.15) are analyzed, it is seen that the drop in the emissions level in 2036 is mostly due to decreased diesel fuel consumption caused by the introduction of gaseous hydrogen fueled vehicles in 2036 (as happened in the base scenario).

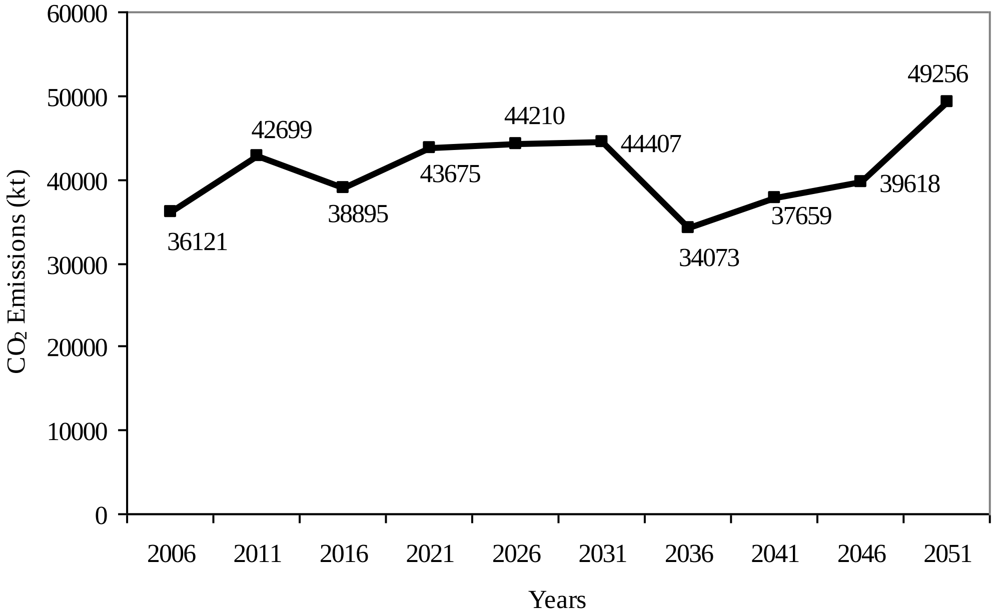

Figure 6.14. CO_2 emissions of the transport sector in scenario 2.1.3.

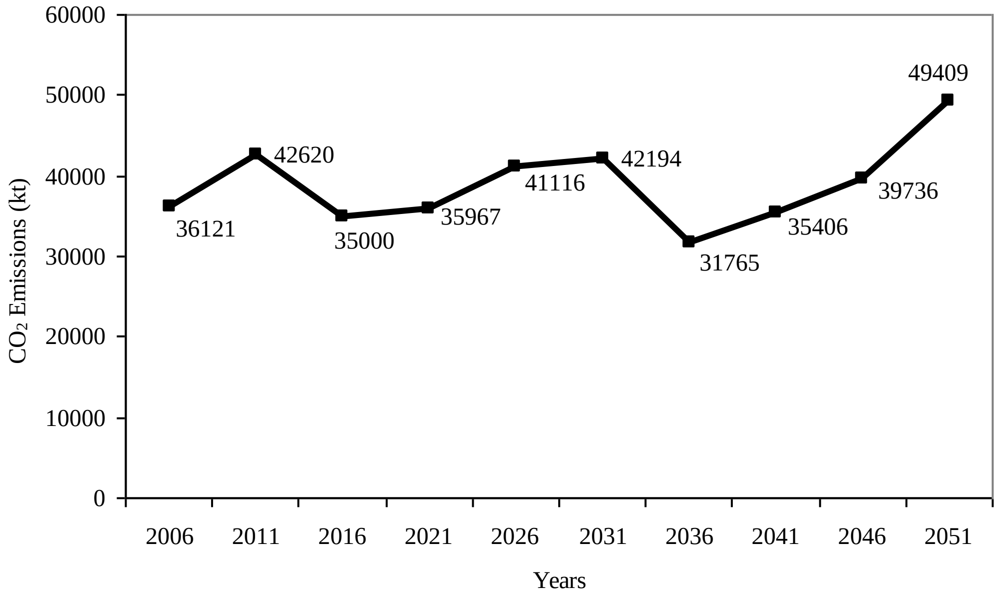

Figure 6.15. CO_2 emissions of the transport sector in scenario 3.1.3.

6.4.5. The 15% and the 30% CO_2 Reduction Scenarios with the 10% modal Shift Scenario (2.2.1 and 3.2.1)

The 15% and the 30% emission reduction scenarios are integrated with the 10% modal shift to generate the dual change scenarios 2.2.1 and 3.2.1. The emission constraints and modal shifts changes are conducted as described in the previous sections.

The results of both scenarios are presented in Table 6.71-78. Besides, modal energy consumptions by fuel types are presented for these scenarios in Appendix A.

Table 6.71. Energy consumptions by fuel types in scenario 2.2.1 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	6.1	7.1	5.2	5.8	6.6	3.8	4.1	0.0
Diesel	322.6	389.4	347.8	378.2	420.1	430.8	294.9	285.4	212.6	148.1
Electricity	1.1	1.4	6.4	19.2	28.7	39.4	64.9	73.7	86.1	87.9
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	76.0
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	99.2	138.0	187.0	270.2
Jet Fuel	15.2	22.3	64.5	80.0	90.0	121.6	136.9	183.0	205.6	205.6
LPG	54.6	97.5	104.5	107.2	127.9	88.5	91.2	127.5	173.4	257.9
Gasoline	110.2	85.0	24.6	42.1	60.0	109.4	153.2	157.5	241.2	275.0
Ethanol	0.0	0.0	73.2	73.2	73.2	69.2	25.8	60.2	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	0.0	1.6	1.6	0.0	1.6	54.5	84.2
Total	503.8	599.0	627.0	707.0	806.7	866.3	872.5	1030.8	1164.5	1404.8

Table 6.72. Share of fuel types in the total energy consumptions in scenario 2.2.1 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	1.0	1.0	0.6	0.7	0.8	0.4	0.4	0.0
Diesel	64.0	65.0	55.5	53.5	52.1	49.7	33.8	27.7	18.3	10.5
Electricity	0.2	0.2	1.0	2.7	3.6	4.5	7.4	7.2	7.4	6.3
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	11.4	13.4	16.1	19.2
Jet Fuel	3.0	3.7	10.3	11.3	11.2	14.0	15.7	17.8	17.7	14.6
LPG	10.8	16.3	16.7	15.2	15.8	10.2	10.5	12.4	14.9	18.4
Gasoline	21.9	14.2	3.9	6.0	7.4	12.6	17.6	15.3	20.7	19.6
Ethanol	0.0	0.0	11.7	10.4	9.1	8.0	3.0	5.8	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.2	4.7	6.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.73. Energy consumptions by fuel types in scenario 3.2.1 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	6.1	7.1	5.5	5.6	6.4	3.8	4.1	0.0
Diesel	322.6	389.1	336.9	288.4	314.5	321.5	249.6	241.5	129.9	54.7
Electricity	1.1	1.4	9.1	16.6	26.1	36.8	71.2	84.3	84.3	84.3
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	88.7	164.7
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	99.2	148.2	213.7	299.4
Jet Fuel	15.2	22.3	64.5	80.0	90.0	117.9	136.9	178.1	131.3	131.3
LPG	54.6	100.0	84.5	137.1	176.0	123.9	88.4	92.0	138.8	197.2
Gasoline	110.2	85.1	0.0	0.0	2.2	61.0	82.3	106.9	221.9	273.7
Ethanol	0.0	0.0	95.8	95.8	94.8	95.8	77.1	82.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	75.5	114.0	114.0	44.4	45.5	137.7	188.0
Total	503.8	601.4	596.8	700.6	823.2	876.5	855.4	982.3	1150.4	1393.3

Table 6.74. Share of fuel types in the total energy consumptions in scenario 3.2.1 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	1.0	1.0	0.7	0.6	0.8	0.4	0.4	0.0
Diesel	64.0	64.7	56.4	41.2	38.2	36.7	29.2	24.6	11.3	3.9
Electricity	0.2	0.2	1.5	2.4	3.2	4.2	8.3	8.6	7.3	6.0
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	11.8
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	11.6	15.1	18.6	21.5
Jet Fuel	3.0	3.7	10.8	11.4	10.9	13.5	16.0	18.1	11.4	9.4
LPG	10.8	16.6	14.2	19.6	21.4	14.1	10.3	9.4	12.1	14.2
Gasoline	21.9	14.2	0.0	0.0	0.3	7.0	9.6	10.9	19.3	19.6
Ethanol	0.0	0.0	16.1	13.7	11.5	10.9	9.0	8.3	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	10.8	13.8	13.0	5.2	4.6	12.0	13.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

In scenarios 2.2.1 and 3.2.1, total diesel consumptions decrease compared with the base scenario. This decrease is based on the added 15% and 30% emissions constraints and 10% modal shift together.

As explained in scenario 1.2.1, total diesel consumptions are reduced with the 10% modal shift. In fact, with the increased freight transport demand in railway and maritime sectors (shifted from road transport vehicles like trucks etc.) and passenger transport demand in intracity buses, diesel consumptions increase in these sectors. But, since the saved diesel energy (from the decreased private car, minibus and intercity bus demands) is more than that increase, total diesel consumptions decrease in the 10% modal shift. In addition, by the contribution of the added 15% and 30% CO_2 emission constraints (that lead to increase in bio-diesel consumption), the diesel consumptions decrease in scenarios 2.2.1 and 3.2.1, compared with the base scenario. Consecutively, bio-diesel consumption s increased in both scenarios, with its use instead of diesel fuel.

Gasoline and LPG consumptions are decreased; first with the decrease in private car demand due to the applied %10 modal shift, second, with the increase in ethanol consumption instead of gasoline due to the implemented 15% and 30% CO_2 emission reductions. Lastly, due to the mentioned CO_2 emission reductions, electric powered private cars (TC1 and TC2) are introduced to the market after 2021 in scenario 2.2.1 and after 2016 in scenario 3.2.1. Therefore, while gasoline consumptions are decreased, ethanol and electricity consumptions are increased in these two scenarios compared with the base scenario. Ethanol is deployed for gasoline fueled private cars between 2016 and 2041. But, after 2041, gasoline consumptions increase again (since it costs less than ethanol's) due to already satisfied emission constraint (by the savings from other technologies) in the last 10 years of the planning horizon.

Electricity consumptions are also increased with the increased demands (due to the 10% modal shift) in freight trains, high-speed trains, intracity buses and metros. Besides, with the mentioned %10 demand shift, CNG consumption of intracity buses increase in these two scenarios compared with the base scenario.

Regarding gaseous hydrogen consumptions, it is seen that, with the decreased heavy truck and tractor trailer demands (from 10% modal shift) total gaseous hydrogen consumptions from base scenario to scenario 2.2.1. But, from scenario 2.2.1 to 3.2.1, with the contribution of increased CO_2 emission reduction rates (from 15% to 30%), hydrogen consumption of intercity and intracity buses are increased.

Finally, it is seen that, due to the increased demand in passenger air transport (caused by 10% modal shift) the total jet fuel and liquefied hydrogen consumptions are increased compared with the base scenario. But, compared with scenario 2.2.1, in scenario 3.2.1, jet fuel is consumed less, whereas liquefied hydrogen is consumed more due to the increased emission reduction rate (from 15% to 30%).

Table 6.75. CO_2 emissions by fuel types in scenario 2.2.1 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	340	396	290	323	369	212	229	0
Diesel	23908	28852	25771	28021	31130	31919	21850	21150	15753	10973
Jet Fuel	1055	1542	4471	5546	6239	8430	9484	12681	14246	14246
LPG	3443	6151	6591	6765	8068	5586	5758	8048	10943	16272
Gasoline	7716	5950	1722	2947	4200	7655	10720	11024	16886	19246
L. Hydrogen	0	0	0	0	0	0	0	0	0	3919
Total	36121	42689	38895	43675	49927	53913	48180	53115	58057	64657

Table 6.76. Share of fuel types in the total CO_2 emissions in scenario 2.2.1 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	0.9	0.9	0.6	0.6	0.8	0.4	0.4	0.0
Diesel	66.2	67.6	66.3	64.2	62.4	59.2	45.3	39.8	27.1	17.0
Jet Fuel	2.9	3.6	11.5	12.7	12.5	15.6	19.7	23.9	24.5	22.0
LPG	9.5	14.4	16.9	15.5	16.2	10.4	12.0	15.2	18.8	25.2
Gasoline	21.4	13.9	4.4	6.7	8.4	14.2	22.3	20.8	29.1	29.8
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.77. CO_2 emissions by fuel types in scenario 3.2.1 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	340	396	309	314	360	212	229	0
Diesel	23908	28834	24961	21374	23305	23820	18498	17898	9624	4052
Jet Fuel	1055	1542	4471	5546	6239	8172	9484	12344	9099	9099
LPG	3443	6309	5328	8652	11107	7820	5577	5803	8756	12444
Gasoline	7716	5960	0	0	156	4272	5759	7484	15530	19159
L. Hydrogen	0	0	0	0	0	0	0	0	4574	8493
Total	36121	42840	35100	35967	41116	44399	39678	43741	47811	53247

Table 6.78. Share of fuel types in the total CO_2 emissions in scenario 3.2.1 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	1.0	1.1	0.8	0.7	0.9	0.5	0.5	0.0
Diesel	66.2	67.3	71.1	59.4	56.7	53.6	46.6	40.9	20.1	7.6
Jet Fuel	2.9	3.6	12.7	15.4	15.2	18.4	23.9	28.2	19.0	17.1
LPG	9.5	14.7	15.2	24.1	27.0	17.6	14.1	13.3	18.3	23.4
Gasoline	21.4	13.9	0.0	0.0	0.4	9.6	14.5	17.1	32.5	36.0
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.6	16.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

When CO_2 emissions of these two scenarios are analyzed, it is seen that the total emissions realize lower than the base scenario mostly due to 15% and 30% CO_2 emission reductions. Because, total CO_2 emission values realize the same as the ones in scenarios 2.1.1 and 3.1.1.

Regarding fuel types, in both scenarios 2.2.1 and 3.2.1, CO_2 emissions from diesel consumption are lower than the base scenario due to the mentioned impacts of 15% and 30% CO_2 emission reduction and 10% modal shift. The reason for this decrease is based on the deployment of bio-diesel instead of conventional diesel fuel (due to CO_2 emission restriction) and saved diesel consumptions (due to 10% modal shift) which are explained in detail in the energy consumption part.

Besides, CO_2 emissions from LPG consumption are also decreased due to decreased private car demand caused by 10% modal shift. Regarding the emissions from gasoline consumption, it is seen that the total emissions are decreased mostly due to the introduction of ethanol fueled private cars (by 15% and 30% emissions reduction). Besides, introduction of electric powered private cars and decreased private car demand values cause gasoline consumptions to decrease in these two scenarios compared with the base scenario. But, as explained in the energy consumption part, in the last 10 years of the planning horizon, ethanol consumption decreases, and therefore, the emissions resulting from gasoline consumptions increase in both scenarios.

CO_2 emissions from CNG consumption also increased in these scenarios compared to the base scenario, due to the increased demand in intracity buses using CNG fuel. Lastly, due to the impact of 10% modal shift and 15%-30% CO_2 emission reductions, emissions resulting from jet fuel consumption decreases, whereas emissions from liquefied hydrogen increases in both scenarios leading to lower emissions from air transport compared with the base scenario.

When the trend of CO_2 emissions (Figure 6.16 and 6.17) are analyzed, it is seen that the drop in the emissions level in 2036 is mostly due to decreased diesel fuel consumption caused by the introduction of gaseous hydrogen fueled vehicles in 2036 (as happened in the base scenario and scenarios 2.1.1 and 3.1.1 as well).

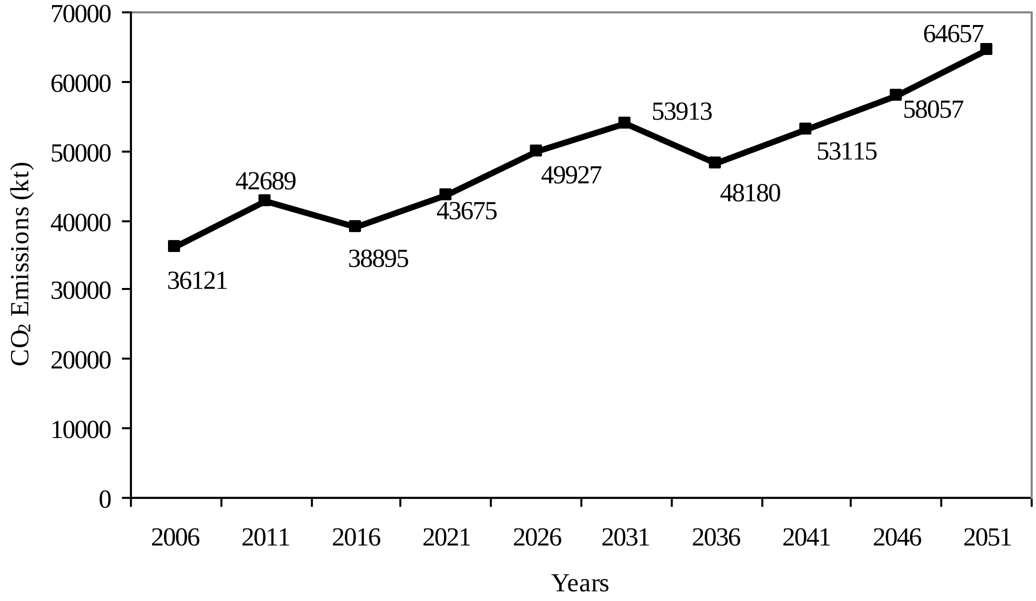

Figure 6.16. CO_2 emissions of the transport sector in scenario 2.2.1.

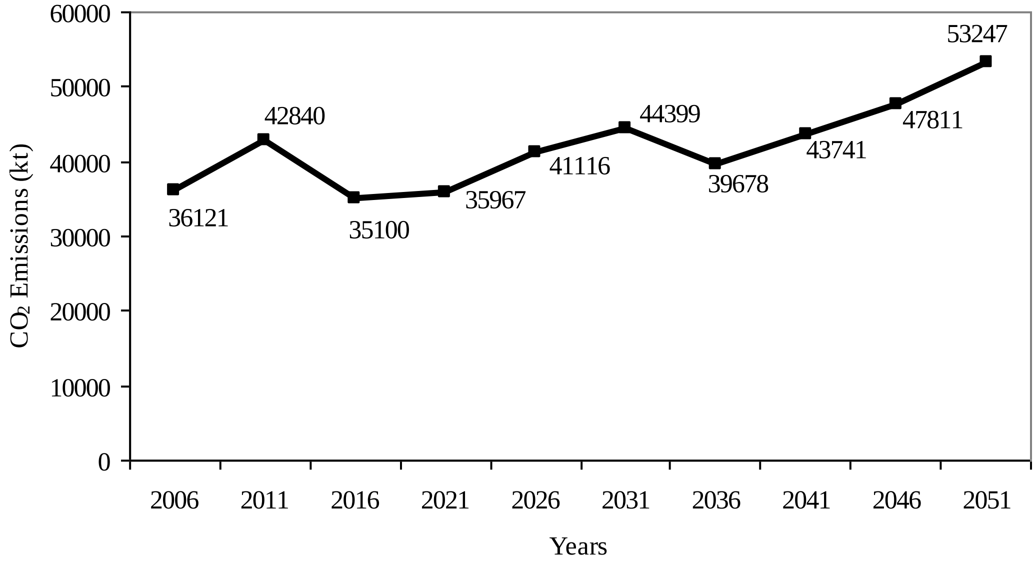

Figure 6.17. CO_2 emissions of the transport sector in scenario 3.2.1.

6.4.6. The 15% and the 30% CO_2 Reduction Scenarios with 20% Modal Shift Scenario (2.3.1 and 3.3.1)

The 15% and the 30% emission reduction scenarios are integrated with the 20% modal shift to generate the dual change scenarios 2.3.1 and 3.3.1. The emission constraints and modal shifts changes are conducted as described in the previous sections.

The results of both scenarios are presented in Table 6.79-86. Besides, modal energy consumptions by fuel types are presented for these scenarios in Appendix A.

Table 6.79. Energy consumptions by fuel types in scenario 2.3.1 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	6.7	7.7	5.6	6.2	7.1	4.1	4.4	0.0
Diesel	322.6	389.4	328.7	356.7	397.4	406.9	283.6	275.8	208.5	160.6
Electricity	1.1	1.4	7.9	19.7	31.0	43.7	67.1	81.3	83.6	83.6
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.1	119.0
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	88.2	122.7	182.7	265.1
Jet Fuel	15.2	22.3	96.8	112.7	118.7	149.2	165.6	211.7	209.9	209.9
LPG	54.6	97.5	98.2	100.9	119.2	119.1	125.7	157.7	198.2	232.9
Gasoline	110.2	85.0	18.0	37.6	63.2	79.4	105.1	111.9	192.1	248.3
Ethanol	0.0	0.0	66.7	66.7	57.4	56.1	37.1	59.7	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	53.5	74.9
Total	503.8	599.0	623.0	702.1	792.4	860.6	879.6	1024.7	1169.0	1394.4

Table 6.80. Share of fuel types in the total energy consumptions in scenario 2.3.1 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	1.1	1.1	0.7	0.7	0.8	0.4	0.4	0.0
Diesel	64.0	65.0	52.8	50.8	50.1	47.3	32.2	26.9	17.8	11.5
Electricity	0.2	0.2	1.3	2.8	3.9	5.1	7.6	7.9	7.2	6.0
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	8.5
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	10.0	12.0	15.6	19.0
Jet Fuel	3.0	3.7	15.5	16.0	15.0	17.3	18.8	20.7	18.0	15.1
LPG	10.8	16.3	15.8	14.4	15.0	13.8	14.3	15.4	17.0	16.7
Gasoline	21.9	14.2	2.9	5.4	8.0	9.2	11.9	10.9	16.4	17.8
Ethanol	0.0	0.0	10.7	9.5	7.2	6.5	4.2	5.8	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	5.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.81. Energy consumptions by fuel types in scenario 3.3.1 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	6.7	7.7	6.0	6.0	6.9	4.1	4.4	0.0
Diesel	322.6	389.3	317.5	271.1	298.0	314.4	247.7	245.4	145.2	79.8
Electricity	1.1	1.4	9.4	18.1	29.4	42.1	77.6	91.0	92.1	92.1
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	111.7	194.7
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	88.2	139.9	201.6	284.0
Jet Fuel	15.2	22.3	96.8	112.7	118.7	145.6	165.6	211.7	146.6	146.6
LPG	54.6	100.5	75.9	120.7	165.7	110.8	75.1	78.2	119.4	171.6
Gasoline	110.2	85.2	0.0	0.3	0.3	52.7	67.4	81.8	190.9	233.0
Ethanol	0.0	0.0	89.5	89.5	89.5	89.5	77.1	82.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	73.5	96.4	96.4	35.1	30.7	117.1	166.4
Total	503.8	602.1	595.8	693.6	803.9	857.4	840.7	964.7	1128.8	1368.1

Table 6.82. Share of fuel types in the total energy consumptions in scenario 3.3.1 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	1.1	1.1	0.7	0.7	0.8	0.4	0.4	0.0
Diesel	64.0	64.7	53.3	39.1	37.1	36.7	29.5	25.4	12.9	5.8
Electricity	0.2	0.2	1.6	2.6	3.7	4.9	9.2	9.4	8.2	6.7
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.9	14.2
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	10.5	14.5	17.9	20.8
Jet Fuel	3.0	3.7	16.2	16.2	14.8	17.0	19.7	21.9	13.0	10.7
LPG	10.8	16.7	12.7	17.4	20.6	12.9	8.9	8.1	10.6	12.5
Gasoline	21.9	14.1	0.0	0.0	0.0	6.1	8.0	8.5	16.9	17.0
Ethanol	0.0	0.0	15.0	12.9	11.1	10.4	9.2	8.5	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	10.6	12.0	11.2	4.2	3.2	10.4	12.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

In scenarios 2.3.1 and 3.3.1, total diesel consumptions decrease compared with the base scenario. This decrease is based on the added 15% and 30% emissions constraints and 20% modal shift together.

As explained in scenario 1.3.1, total diesel consumptions are reduced with 20% modal shift. In fact, with the increased freight transport demand in railway and maritime sectors (shifted from road transport vehicles like trucks etc.) and passenger transport demand in intracity buses, diesel consumptions increase in these sectors. But, since the saved diesel energy (from the decreased private car, minibus and intercity bus demands) is more than that increase, total diesel consumptions decrease in 20% modal shift. In addition, by the contribution of the added 15% and 30% CO_2 emission constraints (that lead to increase in bio-diesel consumption), the diesel consumptions decrease in scenarios 2.3.1 and 3.3.1, compared with the base scenario. Consecutively, bio-diesel consumption increased in both scenarios, with its use instead of diesel fuel.

Gasoline and LPG consumptions are decreased; first with the decrease in private car demand due to applied 20% modal shift, second, with the increase in ethanol consumption instead of gasoline due to the implemented 15% and 30% CO_2 emission reductions. Lastly, due to the mentioned CO_2 emission reductions, electric powered private cars (TC1 and TC2 in scenario 2.3.1 and TC1, TC2 and TC3 in scenario 3.3.1) are introduced to the market after 2021 and 2026 in scenarios 2.3.1 and 3.3.1, respectively. Therefore, while gasoline consumptions are decreased, ethanol and electricity consumptions are increased in these two scenarios compared with the base scenario. Ethanol is deployed for gasoline fueled private cars between 2016 and 2041. But, after 2041, gasoline consumptions increase again (since its cost is less than ethanol's in these years) due to already satisfied emission bound (by the savings from other technologies) in the last 10 years of the planning horizon.

Electricity consumptions are also increased with the increased demands (due to 20% modal shift) in freight trains, high-speed trains, intracity buses and metros. Besides, with the mentioned %20 demand shift, CNG consumption of intracity buses are increased in these two scenarios compared with the base scenario.

Regarding gaseous hydrogen consumptions, it is seen that, with the decreased heavy truck and tractor trailer demands (from the 20% modal shift) total gaseous hydrogen consumptions from base scenario to scenario 2.3.1. But, from scenario 2.3.1 to 3.3.1, with the contribution of increased CO_2 emission reduction rates (from 15% to 30%), hydrogen consumption of intercity and intracity buses are increased, leading to higher total hydrogen consumption.

Finally, it is seen that, due to the increased demand in airway passenger transport (caused by the 20% modal shift) the total jet fuel and liquefied hydrogen consumptions are increased compared with the base scenario. But, compared with scenario 2.3.1, in scenario 3.3.1, jet fuel is consumed less, whereas liquefied hydrogen is consumed more due to the increased emission reduction rate (from 15% to 30%).

Table 6.83. CO_2 emissions by fuel types in scenario 2.3.1 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	376	434	315	347	397	228	246	0
Diesel	23908	28852	24354	26432	29444	30153	21017	20440	15448	11899
Jet Fuel	1055	1542	6707	7809	8222	10339	11478	14667	14545	14545
LPG	3443	6151	6197	6366	7522	7515	7933	9950	12507	14698
Gasoline	7716	5951	1261	2634	4424	5559	7355	7830	13450	17377
L. Hydrogen	0	0	0	0	0	0	0	0	1861	6138
Total	36121	42690	38895	43675	49927	53913	48180	53115	58057	64657

Table 6.84. Share of fuel types in the total CO_2 emissions in scenario 2.3.1 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	1.0	1.0	0.6	0.6	0.8	0.4	0.4	0.0
Diesel	66.2	67.6	62.6	60.5	59.0	55.9	43.6	38.5	26.6	18.4
Jet Fuel	2.9	3.6	17.2	17.9	16.5	19.2	23.8	27.6	25.1	22.5
LPG	9.5	14.4	15.9	14.6	15.1	13.9	16.5	18.7	21.5	22.7
Gasoline	21.4	13.9	3.2	6.0	8.9	10.3	15.3	14.7	23.2	26.9
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	9.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.85. CO_2 emissions by fuel types in scenario 3.3.1 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	376	434	335	338	387	228	246	0
Diesel	23908	28846	23527	20090	22084	23294	18354	18187	10755	5915
Jet Fuel	1055	1542	6707	7809	8222	10090	11478	14667	10157	10157
LPG	3443	6343	4790	7615	10455	6989	4741	4934	7533	10825
Gasoline	7716	5961	0	19	19	3689	4717	5725	13359	16312
L. Hydrogen	0	0	0	0	0	0	0	0	5761	10038
Total	36121	42886	35400	35967	41116	44399	39678	43741	47811	53247

Table 6.86. Share of fuel types in the total CO_2 emissions in scenario 3.3.1 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	1.1	1.2	0.8	0.8	1.0	0.5	0.5	0.0
Diesel	66.2	67.3	66.5	55.9	53.7	52.5	46.3	41.6	22.5	11.1
Jet Fuel	2.9	3.6	18.9	21.7	20.0	22.7	28.9	33.5	21.2	19.1
LPG	9.5	14.8	13.5	21.2	25.4	15.7	11.9	11.3	15.8	20.3
Gasoline	21.4	13.9	0.0	0.1	0.0	8.3	11.9	13.1	27.9	30.6
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.0	18.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

When CO_2 emissions of these two scenarios are analyzed, it is seen that the total emissions realize lower than the base scenario mostly due to 15% and 30% CO_2 emission reductions. Because, total CO_2 emissions are realized the same as the ones in scenarios 2.1.1 and 3.1.1.

Regarding fuel types, in both scenarios 2.3.1 and 3.3.1, CO_2 emissions from diesel consumption are lower than the base scenario due to the mentioned impacts of the 15% and the 30% CO_2 emission reduction and the 20% modal shift. The reason is the deployment of bio-diesel instead of conventional diesel fuel (due to CO_2 emission restriction) and saved diesel consumptions (due to 20% modal shift) which are explained in detail in the energy consumption part.

Besides, CO_2 emissions from LPG consumption are also decreased due to decreased private car demand caused by the 20% modal shift. Regarding the emissions from gasoline consumption, it is seen that the total emissions are decreased mostly due to the introduction of ethanol fueled private cars (caused by the 15% and the 30% emissions reduction). Besides, introduction of electric powered private cars and decreased private car demand values lead gasoline consumptions to decrease in these two scenarios compared with the base scenario. But, as explained in the energy consumption part, in the last 10 years of the planning horizon, ethanol consumption decreases, and therefore, the emissions resulting from gasoline consumptions increase in both scenarios.

CO_2 emissions from CNG consumption also increased in these scenarios compared to the base scenario, due to the increased demand in intracity buses using CNG fuel. Lastly, due to the impact of the 20% modal shift and the 15%-30% CO_2 emission reductions, emissions resulting from jet fuel consumption decreases, whereas emissions from liquefied hydrogen increases in both scenarios leading to lower emissions from air transport compared with the base scenario.

When the trend of CO_2 emissions (Figure 6.18 and 6.19) are analyzed, it is seen that the drop in the emissions level in 2036 is mostly due to decreased diesel fuel consumption caused by the introduction of gaseous hydrogen fueled vehicles in 2036 (as happened in the base scenario and scenarios 2.1.1 and 3.1.1 as well).

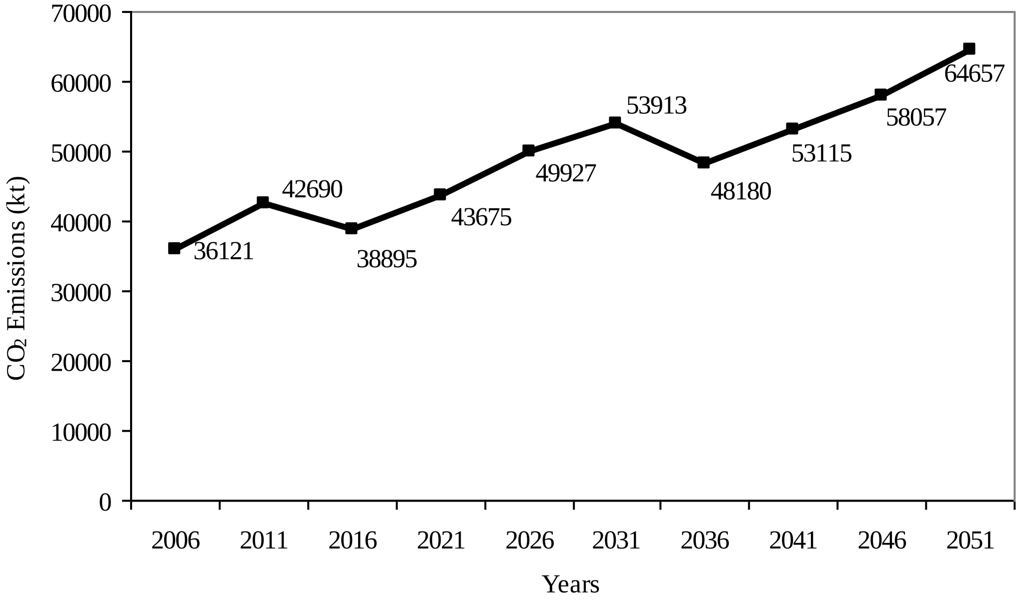

Figure 6.18. CO_2 emissions of the transport sector in scenario 2.3.1.

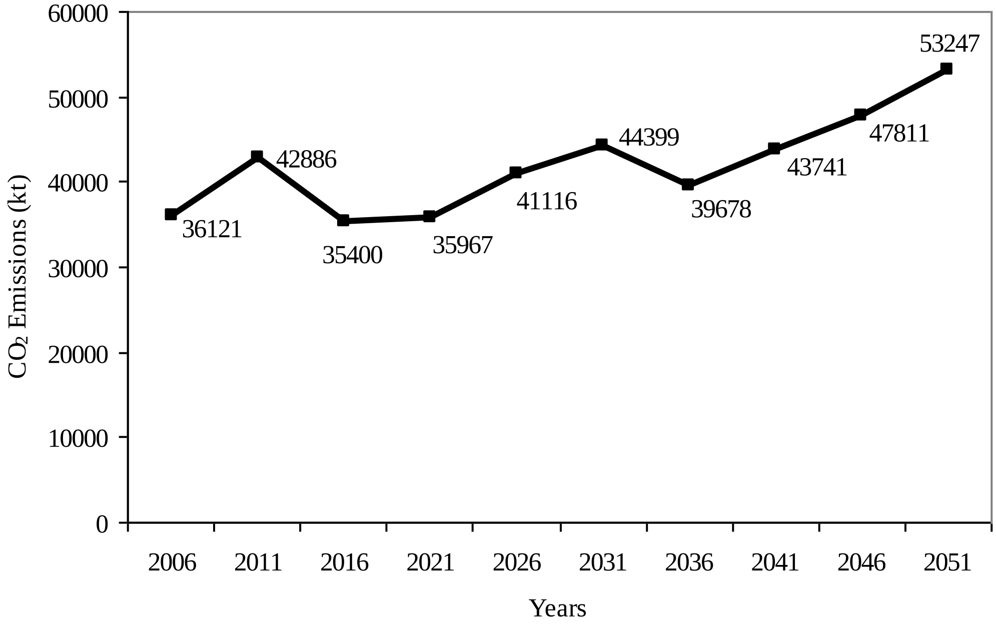

Figure 6.19. CO_2 emissions of the transport sector in scenario 3.3.1.

6.5. The Ternary Case Scenarios

In this section, scenarios are created by ternary combinations of the alternative cases (cases featuring triple factor change) defined in Table 6.1 and their results are presented.

6.5.1. The 10% and the 20% Modal Shift Scenarios with 15% CO_2 Emission Reduction Scenario and the 15% Auto Efficiency Improvement and 20% Fuel Price Increase Scenario (2.2.2 and 2.3.2).

The 10% and the 20% modal shift scenarios are integrated with the 15% CO_2 emissions reduction scenario and the 15%-20% auto efficiency and fuel price increase scenario to generate the triple change scenarios 2.2.2 and 2.3.2. The emission constraints, modal shifts and efficiency and fuel price changes are conducted as described in the previous sections.

The results of both scenarios are presented in Table 6.87-94. Besides, modal energy consumptions by fuel types are presented for these scenarios in Appendix A.

Table 6.87. Energy consumptions by fuel types in scenario 2.2.2 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	6.1	7.1	7.1	7.2	6.4	3.8	4.1	0.0
Diesel	322.6	389.4	346.1	331.9	376.1	383.3	243.4	241.5	43.0	54.7
Electricity	1.1	1.4	6.4	14.0	23.5	34.1	50.0	64.2	76.5	87.9
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	206.8	321.6
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	99.2	138.0	187.0	257.3
Jet Fuel	15.2	22.3	64.5	81.8	90.0	121.6	136.9	178.1	32.4	0.0
LPG	54.6	97.5	103.7	116.8	134.7	127.6	153.7	174.3	214.0	289.7
Gasoline	110.2	85.1	27.1	80.7	98.9	123.3	74.6	102.9	194.9	207.3
Ethanol	0.0	0.0	69.6	36.1	34.8	15.0	69.6	69.6	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	44.9	44.9	44.9	44.9	38.8	218.3	173.5
Total	503.8	599.1	623.5	713.2	809.9	856.9	878.6	1011.2	1177.0	1392.0

Table 6.88. Share of fuel types in the total energy consumptions in scenario 2.2.2 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	1.0	1.0	0.9	0.8	0.7	0.4	0.3	0.0
Diesel	64.0	65.0	55.5	46.5	46.4	44.7	27.7	23.9	3.7	3.9
Electricity	0.2	0.2	1.0	2.0	2.9	4.0	5.7	6.3	6.5	6.3
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6	23.1
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	11.3	13.6	15.9	18.5
Jet Fuel	3.0	3.7	10.3	11.5	11.1	14.2	15.6	17.6	2.8	0.0
LPG	10.8	16.3	16.6	16.4	16.6	14.9	17.5	17.2	18.2	20.8
Gasoline	21.9	14.2	4.3	11.3	12.2	14.4	8.5	10.2	16.6	14.9
Ethanol	0.0	0.0	11.2	5.1	4.3	1.7	7.9	6.9	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	6.3	5.5	5.2	5.1	3.8	18.6	12.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.89. Energy consumptions by fuel types in scenario 2.3.2 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	6.7	7.7	7.7	7.8	6.9	4.1	4.4	0.0
Diesel	322.6	389.4	327.4	321.5	362.0	366.9	242.8	270.1	55.6	65.6
Electricity	1.1	1.4	7.9	16.7	27.9	40.6	57.3	74.6	83.6	83.6
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	237.1	369.7
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	88.2	122.7	173.7	256.1
Jet Fuel	15.2	22.3	96.8	114.5	118.7	149.2	165.6	211.7	41.6	0.0
LPG	54.6	97.5	98.2	110.0	125.8	113.7	137.0	155.3	190.3	259.6
Gasoline	110.2	85.2	19.3	64.9	93.0	121.1	64.5	89.7	175.1	184.0
Ethanol	0.0	0.0	65.5	37.8	24.8	0.0	65.5	65.5	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	34.9	34.9	34.9	34.9	0.0	201.1	166.2
Total	503.8	599.1	621.9	707.9	794.8	834.1	862.8	993.5	1162.4	1384.9

Table 6.90. Share of fuel types in the total energy consumptions in scenario 2.3.2 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	1.1	1.1	1.0	0.9	0.8	0.4	0.4	0.0
Diesel	64.0	65.0	52.6	45.4	45.5	44.0	28.1	27.2	4.8	4.7
Electricity	0.2	0.2	1.3	2.4	3.5	4.9	6.6	7.5	7.2	6.0
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.4	26.7
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	10.2	12.3	14.9	18.5
Jet Fuel	3.0	3.7	15.6	16.2	14.9	17.9	19.2	21.3	3.6	0.0
LPG	10.8	16.3	15.8	15.5	15.8	13.6	15.9	15.6	16.4	18.7
Gasoline	21.9	14.2	3.1	9.2	11.7	14.5	7.5	9.0	15.1	13.3
Ethanol	0.0	0.0	10.5	5.3	3.1	0.0	7.6	6.6	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	4.9	4.4	4.2	4.0	0.0	17.3	12.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

In scenarios 2.2.2 and 2.3.2, total diesel consumptions decrease compared with the base scenario. The reason for this decrease is the deployment of bio-diesel instead of conventional diesel fuel (due to the impact of the 15% CO_2 emissions reduction constraint). Besides, diesel consumptions decrease from scenario 2.2.2 to 2.3.2 due to the increased modal shift from 10% to 20%. In fact, with the increased freight transport demand in railway and maritime sectors (shifted from road transport vehicles like trucks etc.) and passenger transport demand in intracity buses, diesel consumptions increase in these sectors. But, since the saved diesel energy (from the decreased private car, minibus and intercity bus demands) is more than that increase, total diesel consumptions decrease from scenario 2.2.2 to 2.3.2. In addition, with the contribution of the 15%-20% efficiency improvement and fuel price increase scenario, diesel consumption decreases in private cars.

Compared with the base scenario, gasoline and LPG consumptions are decreased with use of ethanol in private cars (due to the impact of the 15% CO_2 emissions reduction) and improved auto efficiencies. Besides, among scenarios 2.2.2 and 2.3.2, since the transport demand for private cars decrease (due to modal shift change from 10% to 20%) it leads to lower gasoline and LPG consumptions in scenario 2.3.2. Lastly, due to the mentioned CO_2 emission reduction, electric powered private cars (TC1) are introduced to the market after 2036. Ethanol is deployed for gasoline fueled private cars between 2016 and 2041. But, after 2041, gasoline consumptions increase again (since its cost is less than ethanol's in these years) due to already satisfied emission constraints in the last 10 years of the planning horizon.

Electricity consumptions are also increased with the increased demands in freight trains, high-speed trains, intracity buses and metros (due to 10% and 20% modal shifts). The introduction of electric powered private cars also contributes to the increase total electricity consumption. Besides, with the mentioned demand shifts, CNG consumption of intracity buses increase in these two scenarios compared with the base scenario.

Regarding gaseous hydrogen consumptions, it is seen that, with the decreased heavy truck and tractor trailer demands (from 10% and 20% modal shifts) total gaseous hydrogen consumption is also decrease in these two scenarios compared to the base scenario.

Finally, it is seen that, although total energy consumption of air transport increases, from the base scenario to scenario 2.2.2, jet fuel consumptions are decreased due to the introduction of liquefied hydrogen with the impact of 15% CO_2 emission reduction constraint. But, with the increased airway demand from scenario 2.2.2 to 2.3.2, the total consumption increases for both jet fuel and liquefied hydrogen.

Table 6.91. CO_2 emissions by fuel types in scenario 2.2.2 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	340	396	396	401	360	212	229	0
Diesel	23908	28852	25644	24594	27869	28400	18033	17898	3185	4052
Jet Fuel	1055	1542	4471	5666	6239	8430	9484	12344	2246	0
LPG	3443	6151	6542	7373	8498	8051	9698	10999	13502	18281
Gasoline	7716	5960	1898	5646	6924	8630	5220	7201	13641	14513
L. Hydrogen	0	0	0	0	0	0	0	0	10664	16579
Total	36121	42699	38895	43675	49927	53913	42795	48654	43468	53425

Table 6.92. Share of fuel types in the total CO_2 emissions in scenario 2.2.2 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	0.9	0.9	0.8	0.7	0.8	0.4	0.5	0.0
Diesel	66.2	67.6	65.9	56.3	55.8	52.7	42.1	36.8	7.3	7.6
Jet Fuel	2.9	3.6	11.5	13.0	12.5	15.6	22.2	25.4	5.2	0.0
LPG	9.5	14.4	16.8	16.9	17.0	14.9	22.7	22.6	31.1	34.2
Gasoline	21.4	14.0	4.9	12.9	13.9	16.0	12.2	14.8	31.4	27.2
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.5	31.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.93. CO_2 emissions by fuel types in scenario 2.3.2 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	376	434	434	436	387	228	246	0
Diesel	23908	28852	24261	23823	26825	27188	17994	20017	4120	4863
Jet Fuel	1055	1542	6707	7931	8222	10339	11478	14667	2885	0
LPG	3443	6151	6197	6941	7938	7171	8647	9796	12005	16382
Gasoline	7716	5961	1354	4545	6507	8473	4512	6276	12254	12878
L. Hydrogen	0	0	0	0	0	0	0	0	12224	19064
Total	36121	42700	38895	43675	49927	53607	43019	50984	43734	53187

Table 6.94. Share of fuel types in the total CO_2 emissions in scenario 2.3.2 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	1.0	1.0	0.9	0.8	0.9	0.4	0.6	0.0
Diesel	66.2	67.6	62.4	54.5	53.7	50.7	41.8	39.3	9.4	9.1
Jet Fuel	2.9	3.6	17.2	18.2	16.5	19.3	26.7	28.8	6.6	0.0
LPG	9.5	14.4	15.9	15.9	15.9	13.4	20.1	19.2	27.5	30.8
Gasoline	21.4	14.0	3.5	10.4	13.0	15.8	10.5	12.3	28.0	24.2
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.0	35.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

When CO_2 emissions of these two scenarios are analyzed, it is seen that the total emissions realize lower than the base scenario due to the impact of the 15% CO_2 emission reduction constraint and the 15%-20% auto efficiency and fuel price change scenario. From 2006 to 2031, emissions follow a similar trend with 15% reduction scenario but after 2036, they follow a similar path with the 15%-20% auto efficiency and fuel price change scenario.

Regarding fuel types, in both scenarios 2.2.2 and 2.3.2, CO_2 emissions from diesel consumption realize lower than the base scenario, due to the increased bio-diesel consumption and reduced diesel consumptions by improved vehicle efficiencies in private cars and saved diesel fuel from the conducted modal shifts.

Besides, CO_2 emissions from gasoline and LPG consumptions are also decreased due to the consumption of ethanol instead of conventional gasoline, and improved vehicle efficiencies and also reduced private car demand caused by the conducted modal shifts. Besides, it is seen that, compared with the base scenario, the total gasoline emissions are decreased mostly due to the introduction of ethanol fueled private cars (caused by 15% emissions reduction). But, as explained in the energy consumption part, in the last 10 years of the planning horizon, ethanol consumption decreases, and therefore, the emissions resulting from gasoline consumptions increase in both scenarios.

CO_2 emissions from CNG consumption also increased in these scenarios compared to the base scenario, due to the increased demand in intracity buses using CNG fuel. Lastly, due to the impact of the 15% CO_2 emission reduction (introduction of liquefied hydrogen) CO_2 emissions resulting from jet fuel consumption are decreased in scenario 2.2.2 compared with the base scenario. But with the impact of and modal shift changes, jet fuel consumption increases again (as liquefied hydrogen).

When the trend of CO_2 emissions (Figure 6.20 and 6.21) are analyzed, it is seen that the drop in the emissions level in 2016 is due to the introduction of ethanol caused by the 15% CO_2 reduction, whereas the drop in 2036 is mostly due to decreased diesel fuel consumption caused by the introduction of gaseous hydrogen fueled vehicles in 2036 (as happened in the base scenario and scenarios 2.1.1 and 3.1.1 as well). Then the drop in 2046 stems mostly from the substitution of bio-diesel with the conventional diesel fuel.

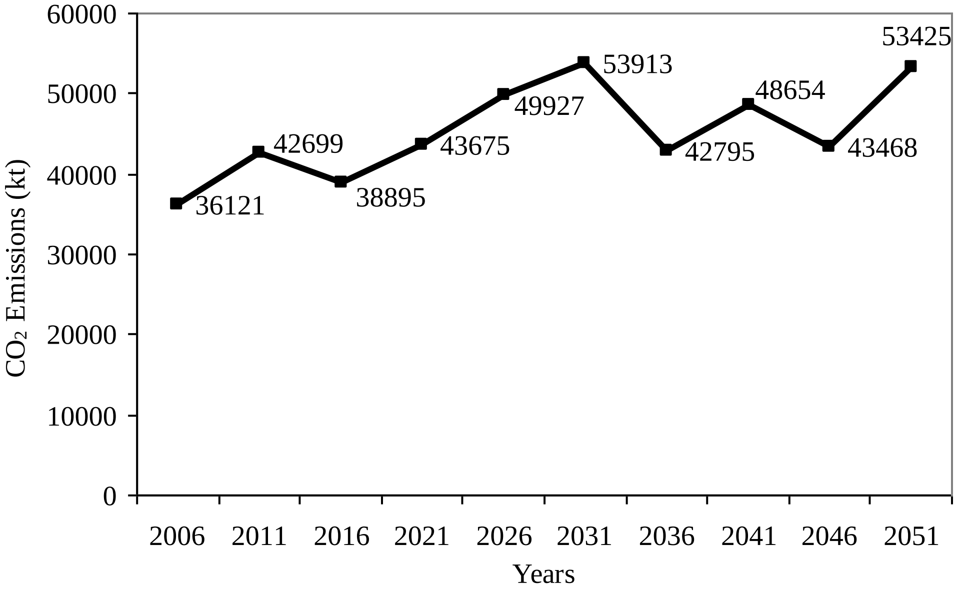

Figure 6.20. CO_2 emissions of the transport sector in scenario 2.2.2.

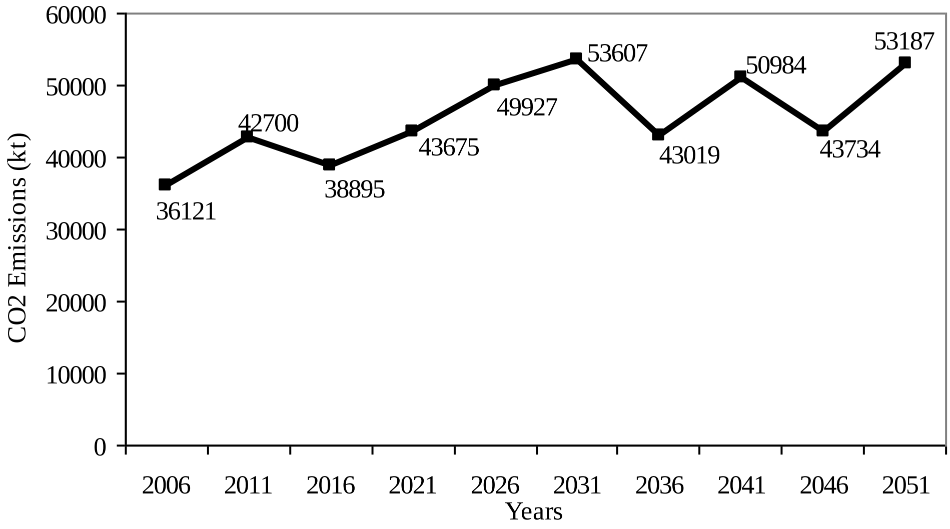

Figure 6.21. CO_2 emissions of the transport sector in scenario 2.3.2.

6.5.2. The 10% and the 20% Modal Shift Scenarios with the 15% CO_2 Emission Reduction Scenario and the 30% Auto Efficiency Improvement and 40% Fuel Price Increase Scenario (2.2.3 and 2.3.3).

The 10% and the 20% modal shift scenarios are integrated with the 15% CO_2 emissions reduction scenario and the 30%-40% auto efficiency and fuel price increase scenario to generate the triple change scenarios 2.2.3 and 2.3.3. The emission constraints, modal shifts and efficiency and fuel price changes are conducted as described in the previous sections.

The results of both scenarios are presented in Table 6.95-102. Besides, modal energy consumptions by fuel types are presented for these scenarios in Appendix A.

Table 6.95. Energy consumptions by fuel types in scenario 2.2.3 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	40.6	88.3	138.6	196.1	6.4	3.8	4.1	0.0
Diesel	322.6	389.4	322.9	259.5	248.3	209.5	195.3	187.4	42.6	54.7
Electricity	1.1	1.4	6.4	14.0	23.5	34.1	59.6	77.8	88.0	88.0
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.5	245.5	321.6
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	99.2	138.0	189.9	275.5
Jet Fuel	15.2	22.3	64.5	81.8	90.0	121.6	136.9	138.6	0.0	0.0
LPG	54.6	97.5	103.7	116.8	134.7	127.6	129.7	150.3	190.0	224.2
Gasoline	110.2	85.1	24.1	92.2	79.7	71.5	68.0	86.6	181.6	241.3
Ethanol	0.0	0.0	72.7	27.0	56.6	69.2	72.7	72.7	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	63.3	86.1	93.1	93.1	93.1	218.7	173.5
Total	503.8	599.1	634.8	742.9	857.4	922.8	860.8	996.6	1160.4	1378.8

Table 6.96. Share of fuel types in the total energy consumptions in scenario 2.2.3 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	6.4	11.9	16.2	21.3	0.7	0.4	0.4	0.0
Diesel	64.0	65.0	50.9	34.9	29.0	22.7	22.7	18.8	3.7	4.0
Electricity	0.2	0.2	1.0	1.9	2.7	3.7	6.9	7.8	7.6	6.4
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	21.2	23.3
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	11.5	13.8	16.4	20.0
Jet Fuel	3.0	3.7	10.2	11.0	10.5	13.2	15.9	13.9	0.0	0.0
LPG	10.8	16.3	16.3	15.7	15.7	13.8	15.1	15.1	16.4	16.3
Gasoline	21.9	14.2	3.8	12.4	9.3	7.7	7.9	8.7	15.7	17.5
Ethanol	0.0	0.0	11.5	3.6	6.6	7.5	8.4	7.3	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	8.5	10.0	10.1	10.8	9.3	18.9	12.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.97. Energy consumptions by fuel types in scenario 2.3.3 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	37.4	80.0	124.3	175.4	6.9	4.1	4.4	0.0
Diesel	322.6	389.4	307.1	265.3	276.7	247.0	235.4	227.0	51.5	65.6
Electricity	1.1	1.4	7.9	16.7	27.9	40.6	64.0	81.3	83.6	83.6
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54.1	286.8	369.7
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	88.2	122.7	182.7	265.1
Jet Fuel	15.2	22.3	96.8	114.5	118.7	149.2	165.6	167.5	0.0	0.0
LPG	54.6	97.5	98.2	110.0	125.8	113.7	119.1	137.3	172.4	202.6
Gasoline	110.2	85.2	16.3	66.6	71.1	52.5	58.4	84.5	173.0	226.5
Ethanol	0.0	0.0	68.6	36.1	46.7	68.6	68.6	68.6	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	43.4	43.4	43.4	43.4	43.4	205.2	166.2
Total	503.8	599.1	632.2	732.5	834.6	890.3	849.7	990.5	1159.5	1379.3

Table 6.98. Share of fuel types in the total energy consumptions in scenario 2.3.3 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	5.9	10.9	14.9	19.7	0.8	0.4	0.4	0.0
Diesel	64.0	65.0	48.6	36.2	33.2	27.7	27.7	22.9	4.4	4.8
Electricity	0.2	0.2	1.3	2.3	3.3	4.6	7.5	8.2	7.2	6.1
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	24.7	26.8
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	10.4	12.4	15.8	19.2
Jet Fuel	3.0	3.7	15.3	15.6	14.2	16.8	19.5	16.9	0.0	0.0
LPG	10.8	16.3	15.5	15.0	15.1	12.8	14.0	13.9	14.9	14.7
Gasoline	21.9	14.2	2.6	9.1	8.5	5.9	6.9	8.5	14.9	16.4
Ethanol	0.0	0.0	10.8	4.9	5.6	7.7	8.1	6.9	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	5.9	5.2	4.9	5.1	4.4	17.7	12.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

In scenarios 2.2.3 and 2.3.3, total diesel consumption (both the conventional and bio-diesel) decreases compared with the base scenario. The reason for this decrease is the deployment of bio-diesel instead of conventional diesel fuel (due to the impact of the 15% CO_2 emissions reduction constraint). Besides, total sum of diesel consumption decreases from scenario 2.2.3 to 2.3.3, due to the increased modal shift from 10% to 20%. In addition, with the contribution of the 15%-20% efficiency improvement and fuel price increase scenario, diesel consumption decreases in private cars. But, consumption of conventional diesel fuel increases from scenario 2.2.3 to 2.3.3 (meaning that the energy system prefers conventional diesel instead of bio-diesel when shifted form scenario 2.2.3 to 2.3.3). Because, the vehicles whose demands are increased with the modal shift (especially ships), mostly use conventional diesel. But the vehicles, whose demands are decreased (especially private cars) mostly use bio-diesel. Thus, although the total diesel consumptions decrease, conventional diesel consumptions increase.

In addition, introduction of CNG fueled vehicles (due to the impact of the 15%-20% efficiency improvement and fuel price increase scenario) leads to lower diesel consumptions.

Compared with the base scenario, gasoline and LPG consumptions are decreased with use of ethanol in private cars (due to the impact of the 15% CO_2 emissions reduction) and improved auto efficiencies. Besides, among scenarios 2.2.3 and 2.3.3, since the transport demand for private cars decrease (due to modal shift change from 10% to 20%) it leads to lower gasoline and LPG consumptions in scenario 2.3.3. Lastly, due to the mentioned CO_2 emission reduction, electric powered private cars (TC1 and TC2) are introduced to the market after 2036. Ethanol is deployed for gasoline fueled private cars between 2016 and 2041. But, after 2041, gasoline consumptions increase again (since it costs is less ethanol) due to already satisfied emission constraints in the last 10 years of the planning horizon.

Electricity consumptions are also increased with the increased demands in freight trains, high-speed trains, intracity buses and metros (due to 10% and 20% modal shifts). The introduction of electric powered private cars also contributes to the increase total electricity consumption. CNG consumptions are increased mostly due to the introduction of gaseous hydrogen fueled heavy trucks and tractor trailers. Besides, with the mentioned demand shifts, CNG consumption of intracity buses increase in these two scenarios compared with the base scenario.

Regarding gaseous hydrogen consumptions, it is seen that, with the decreased heavy truck and tractor trailer demands (from 10% and 20% modal shifts) total gaseous hydrogen consumption is also decrease in these two scenarios compared to the base scenario.

Finally, it is seen that, although the total energy consumption of air transport increases, from the base scenario to scenario 2.2.3, jet fuel consumptions are decreased due to the introduction of liquefied hydrogen with the impact of the 15% CO_2 emission reduction constraint. But, with the increased airway demand from scenario 2.2.3 to 2.3.3, the total consumptions increase again for both jet fuel and liquefied hydrogen.

Table 6.99. CO_2 emissions by fuel types in scenario 2.2.3 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	2275	4954	7776	11003	360	212	229	0
Diesel	23908	28852	23924	19226	18401	15526	14474	13884	3156	4052
Jet Fuel	1055	1542	4471	5666	6239	8430	9484	9603	0	0
LPG	3443	6151	6542	7373	8498	8051	8183	9484	11988	14150
Gasoline	7716	5960	1683	6457	5576	5004	4758	6059	12713	16892
L. Hydrogen	0	0	0	0	0	0	0	2500	12660	16579
Total	36121	42699	38895	43675	46491	48014	37259	41742	40746	51673

Table 6.100. Share of fuel types in the total CO_2 emissions in scenario 2.2.3 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	5.8	11.3	16.7	22.9	1.0	0.5	0.6	0.0
Diesel	66.2	67.6	61.5	44.0	39.6	32.3	38.8	33.3	7.7	7.8
Jet Fuel	2.9	3.6	11.5	13.0	13.4	17.6	25.5	23.0	0.0	0.0
LPG	9.5	14.4	16.8	16.9	18.3	16.8	22.0	22.7	29.4	27.4
Gasoline	21.4	14.0	4.3	14.8	12.0	10.4	12.8	14.5	31.2	32.7
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	31.1	32.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.101. CO_2 emissions by fuel types in scenario 2.3.3 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	2097	4486	6973	9839	387	228	246	0
Diesel	23908	28852	22754	19657	20503	18300	17444	16818	3818	4863
Jet Fuel	1055	1542	6707	7931	8222	10339	11478	11607	0	0
LPG	3443	6151	6197	6941	7938	7171	7517	8666	10875	12781
Gasoline	7716	5961	1141	4660	4977	3673	4087	5917	12109	15856
L. Hydrogen	0	0	0	0	0	0	0	2791	14788	19064
Total	36121	42700	38895	43675	48614	49321	40914	46027	41835	52564

Table 6.102. Share of fuel types in the total CO_2 emissions in scenario 2.3.3 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	5.4	10.3	14.3	19.9	0.9	0.5	0.6	0.0
Diesel	66.2	67.6	58.5	45.0	42.2	37.1	42.6	36.5	9.1	9.3
Jet Fuel	2.9	3.6	17.2	18.2	16.9	21.0	28.1	25.2	0.0	0.0
LPG	9.5	14.4	15.9	15.9	16.3	14.5	18.4	18.8	26.0	24.3
Gasoline	21.4	14.0	2.9	10.7	10.2	7.4	10.0	12.9	28.9	30.2
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	35.3	36.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

When CO_2 emissions of these two scenarios are analyzed, it is seen that the total emissions realize lower than the base scenario due to the impact of the 15% CO_2 emission reduction constraint and the 30%-40% auto efficiency and fuel price change scenario. From 2006 to 2021, emissions graph follow a similar trend with the 15% reduction scenario but, after 2026, it follow a similar path with the 30%-40% auto efficiency and fuel price change scenario.

Regarding fuel types, in both scenarios 2.2.3 and 2.3.3, CO_2 emissions from diesel consumption are lower than the base scenario, due to the increased bio-diesel consumption and reduced diesel consumptions by improved vehicle efficiencies in private cars and saved diesel fuel from the conducted modal shifts. In addition, introduction of CNG fueled heavy trucks and tractor trailers contribute to the savings from diesel consumption. But, as explained in the energy consumption section, diesel emissions increase from scenario 2.2.3 to 2.3.3, due to increased conventional diesel fuel.

Besides, CO_2 emissions from gasoline and LPG consumptions are also decreased due to the consumption of ethanol instead of conventional gasoline, and improved vehicle efficiencies and also reduced private car demand caused by the conducted modal shifts. Besides, it is seen that, compared with the base scenario, the total gasoline emissions are decreased mostly due to the introduction of ethanol fueled private cars (caused by 15% emissions reduction). But, as explained in the energy consumption part, in the last 10 years of the planning horizon, ethanol consumption decreases, and therefore, the emissions resulting from gasoline consumptions increase in both scenarios.

CO_2 emissions from CNG consumption also increased in these scenarios compared to the base scenario, due to the introduction of CNG fueled trucks and increased demand in intracity buses using CNG fuel.

Lastly, it is seen that, although the total energy consumption of air transport increases, from the base scenario to scenario 2.2.3, jet fuel consumptions are decreased due to the introduction of liquefied hydrogen with the impact of 15% CO_2 emission reduction constraint. But, with the increased airway demand from scenario 2.2.3 to 2.3.3, the total consumption increases for both jet fuel and liquefied hydrogen.

When the trend of CO_2 emissions (Figure 6.22 and 6.23) are analyzed, it is seen that the drop in the emissions level in 2016 is due to the introduction of ethanol caused by the 15% CO_2 reduction, whereas the drop in 2036 is mostly due to decreased CNG fuel consumptions caused by the introduction of gaseous hydrogen fueled trucks in 2036. Then the drop in 2046 stems mostly from the substitution of bio-diesel with the conventional diesel fuel.

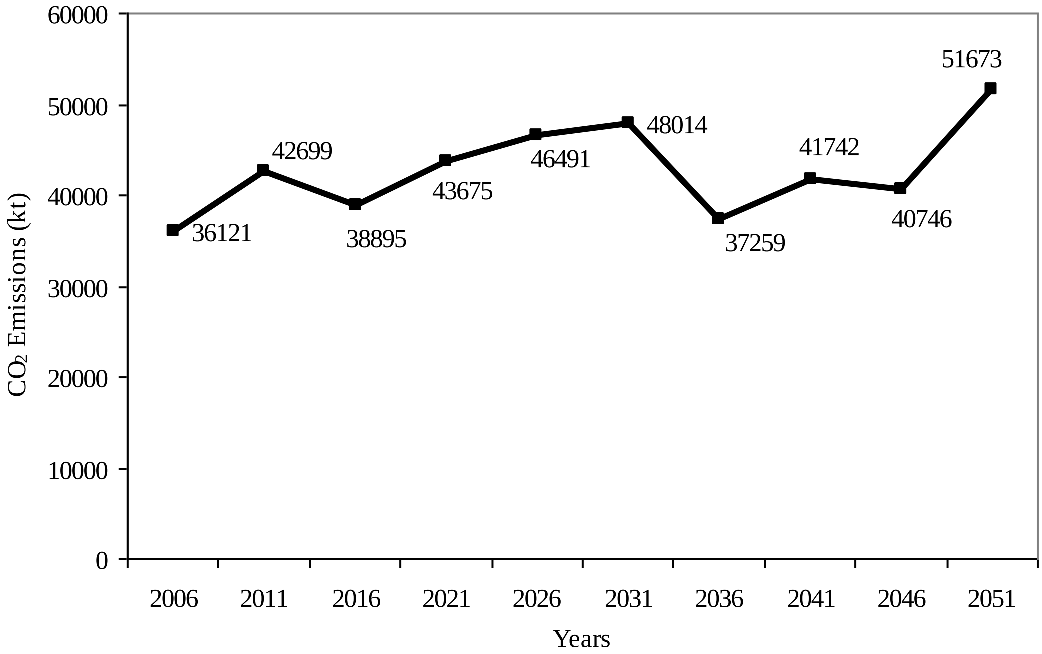

Figure 6.22. CO_2 emissions of the transport sector in scenario 2.2.3.

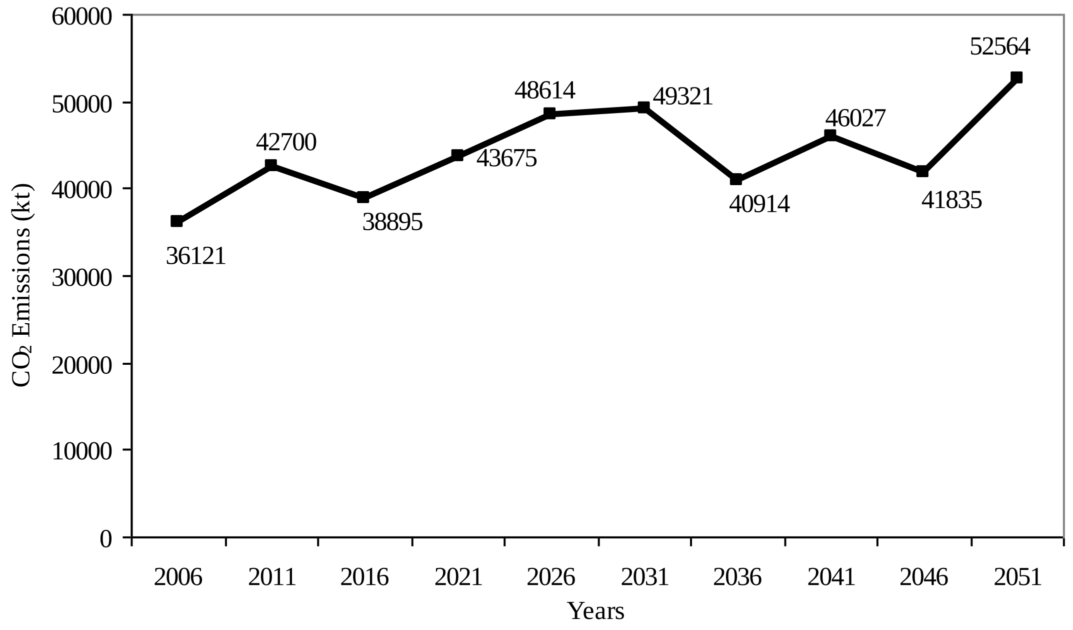

Figure 6.23. CO_2 emissions of the transport sector in scenario 2.3.3.

6.5.3. The 10% and the 20% Modal Shift Scenarios with the 30% CO_2 Emission Reduction Scenario and the 15% Auto Efficiency Improvement and 20% Fuel Price Increase Scenario (3.2.2 and 3.3.2)

The 10% and the 20% modal shift scenarios are integrated with the 30% CO_2 emissions reduction scenario and the 15%-20% auto efficiency and fuel price increase scenario to generate the triple change scenarios 3.2.2 and 3.3.2. The emission constraints, modal shifts and efficiency and fuel price changes are conducted as described in the previous sections.

The results of both scenarios are presented in Table 6.103-110. Besides, modal energy consumptions by fuel types are presented for these scenarios in Appendix A.

Table 6.103. Energy consumptions by fuel types in scenario 3.2.2 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	6.1	7.1	7.1	7.2	6.4	3.8	4.1	0.0
Diesel	322.6	388.2	340.5	234.6	278.9	287.8	197.6	188.1	42.6	54.7
Electricity	1.1	1.4	8.1	15.6	25.1	35.8	50.1	64.3	76.6	83.3
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	207.2	321.6
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	99.2	138.0	187.0	263.7
Jet Fuel	15.2	22.3	64.5	81.8	90.0	121.6	136.9	178.1	32.1	0.0
LPG	54.6	99.0	78.6	129.4	152.2	124.7	151.3	172.9	214.4	301.9
Gasoline	110.2	85.1	0.0	62.3	60.2	91.0	64.7	90.5	195.1	193.8
Ethanol	0.0	0.0	98.4	36.1	56.6	46.5	77.1	82.0	0.0	5.5
Bio-Diesel	0.0	0.0	0.0	134.3	140.4	140.4	90.7	92.3	217.9	172.8
Total	503.8	599.5	596.1	701.1	810.4	855.0	874.0	1010.1	1176.9	1397.2

Table 6.104. Share of fuel types in the total energy consumptions in scenario 3.2.2 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	1.0	1.0	0.9	0.8	0.7	0.4	0.3	0.0
Diesel	64.0	64.8	57.1	33.5	34.4	33.7	22.6	18.6	3.6	3.9
Electricity	0.2	0.2	1.4	2.2	3.1	4.2	5.7	6.4	6.5	6.0
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6	23.0
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	11.3	13.7	15.9	18.9
Jet Fuel	3.0	3.7	10.8	11.7	11.1	14.2	15.7	17.6	2.7	0.0
LPG	10.8	16.5	13.2	18.5	18.8	14.6	17.3	17.1	18.2	21.6
Gasoline	21.9	14.2	0.0	8.9	7.4	10.6	7.4	9.0	16.6	13.9
Ethanol	0.0	0.0	16.5	5.2	7.0	5.4	8.8	8.1	0.0	0.4
Bio-Diesel	0.0	0.0	0.0	19.2	17.3	16.4	10.4	9.1	18.5	12.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.105. Energy consumptions by fuel types in scenario 3.3.2 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	6.7	7.7	7.7	7.8	6.9	4.1	4.4	0.0
Diesel	322.6	388.5	319.6	225.1	271.9	281.5	232.6	209.2	51.5	65.6
Electricity	1.1	1.4	9.4	18.1	29.4	42.1	64.9	79.4	80.5	80.5
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	240.6	369.7
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	88.2	126.3	188.0	270.5
Jet Fuel	15.2	22.3	96.8	114.5	118.7	149.2	165.6	211.7	38.7	0.0
LPG	54.6	100.4	67.1	113.6	158.3	112.9	114.4	133.4	169.2	252.8
Gasoline	110.2	85.2	0.0	53.6	33.2	80.6	47.9	70.4	174.1	173.4
Ethanol	0.0	0.0	89.5	36.1	56.6	40.0	77.1	82.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	119.7	120.9	120.9	44.9	60.9	205.2	165.8
Total	503.8	601.2	589.1	688.5	796.7	834.9	842.6	977.4	1152.3	1378.4

Table 6.106. Share of fuel types in the total energy consumptions in scenario 3.3.2 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	1.1	1.1	1.0	0.9	0.8	0.4	0.4	0.0
Diesel	64.0	64.6	54.3	32.7	34.1	33.7	27.6	21.4	4.5	4.8
Electricity	0.2	0.2	1.6	2.6	3.7	5.0	7.7	8.1	7.0	5.8
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.9	26.8
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	10.5	12.9	16.3	19.6
Jet Fuel	3.0	3.7	16.4	16.6	14.9	17.9	19.7	21.7	3.4	0.0
LPG	10.8	16.7	11.4	16.5	19.9	13.5	13.6	13.7	14.7	18.3
Gasoline	21.9	14.2	0.0	7.8	4.2	9.6	5.7	7.2	15.1	12.6
Ethanol	0.0	0.0	15.2	5.2	7.1	4.8	9.2	8.4	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	17.4	15.2	14.5	5.3	6.2	17.8	12.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

In scenarios 3.2.2 and 3.3.2, total diesel consumption (both the conventional and bio-diesel) decreases compared with the base scenario. The reason for this decrease is the deployment of bio-diesel instead of conventional diesel fuel (due to the impact of the 30% CO_2 emissions reduction constraint). Besides, total sum of diesel consumption decreases from scenario 3.2.2 to 3.3.2, due to the increased modal shift from 10% to 20%. In addition, with the contribution of the 15%-20% efficiency improvement and fuel price increase scenario, diesel consumption decreases in private cars. But, consumption of conventional diesel fuel increases from scenario 3.2.2 to 3.3.2 (meaning that the energy system prefers conventional diesel instead of bio-diesel when shifted from scenario 3.2.2 to 3.3.2). Because, the vehicles whose demands are increased with the modal shift (especially ships), mostly use conventional diesel. But the vehicles, whose demands are decreased (especially private cars) mostly use bio-diesel. Thus, although the total diesel consumptions decrease, conventional diesel consumptions increase.

Compared with the base scenario, gasoline and LPG consumptions are decreased with the use of ethanol in private cars (due to the impact of the 30% CO_2 emissions reduction) and improved auto efficiencies. Besides, among scenarios 3.2.2 and 3.3.2, since the transport demand for private cars decrease (due to modal shift change from 10% to 20%) it leads to lower gasoline and LPG consumptions in scenario 2.3.2. Lastly, due to the mentioned CO_2 emission reduction, electric powered private cars (TC1 and TC2) are introduced to the market after 2036. Ethanol is deployed for gasoline fueled private cars between 2016 and 2041. But, after 2041, gasoline consumptions increase again (since it costs less than ethanol's) due to already satisfied emission constraints in the last 10 years of the planning horizon.

Electricity consumption is also increased with the increased demands in freight trains, high-speed trains, intracity buses and metros (due to 10% and 20% modal shifts). The introduction of electric powered private cars also contributes to the increase in total electricity consumption. Besides, with the mentioned demand shifts, CNG consumption of intracity buses increase in these two scenarios compared with the base scenario. Regarding gaseous hydrogen consumptions, it is seen that, with the decreased heavy truck and tractor trailer demands (from 10% and 20% modal shifts) total gaseous hydrogen consumption is also decreased in these two scenarios compared to the base scenario.

Finally, it is seen that, although the total energy consumption of air transport increases, from the base scenario to scenario 3.2.2, jet fuel consumptions are decreased due to the introduction of liquefied hydrogen with the impact of 15% CO_2 emission reduction constraint. But, with the increased airway demand from scenario 3.2.2 to 3.3.2, the total consumption increases for both jet fuel and liquefied hydrogen.

Table 6.107. CO_2 emissions by fuel types in scenario 3.2.2 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	340	396	396	401	360	212	229	0
Diesel	23908	28763	25230	17386	20663	21329	14642	13938	3156	4052
Jet Fuel	1055	1542	4471	5666	6239	8430	9484	12344	2227	0
LPG	3443	6248	4959	8163	9602	7867	9548	10910	13525	19047
Gasoline	7716	5960	0	4358	4216	6372	4530	6338	13654	13569
L. Hydrogen	0	0	0	0	0	0	0	0	10681	16579
Total	36121	42708	35000	35967	41116	44399	38565	43741	43472	53247

Table 6.108. Share of fuel types in the total CO_2 emissions in scenario 3.2.2 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	1.0	1.1	1.0	0.9	0.9	0.5	0.5	0.0
Diesel	66.2	67.3	72.1	48.3	50.3	48.0	38.0	31.9	7.3	7.6
Jet Fuel	2.9	3.6	12.8	15.8	15.2	19.0	24.6	28.2	5.1	0.0
LPG	9.5	14.6	14.2	22.7	23.4	17.7	24.8	24.9	31.1	35.8
Gasoline	21.4	14.0	0.0	12.1	10.3	14.4	11.7	14.5	31.4	25.5
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.6	31.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.109. CO_2 emissions by fuel types in scenario 3.3.2 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	376	434	434	436	387	228	246	0
Diesel	23908	28787	23685	16679	20150	20861	17239	15503	3818	4863
Jet Fuel	1055	1542	6707	7931	8222	10339	11478	14667	2678	0
LPG	3443	6334	4232	7169	9985	7123	7218	8419	10677	15951
Gasoline	7716	5961	0	3754	2324	5640	3356	4925	12190	12140
L. Hydrogen	0	0	0	0	0	0	0	0	12407	19064
Total	36121	42819	35000	35967	41116	44399	39678	43741	42016	52018

Table 6.110. Share of fuel types in the total CO_2 emissions in scenario 3.3.2 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	1.1	1.2	1.1	1.0	1.0	0.5	0.6	0.0
Diesel	66.2	67.2	67.7	46.4	49.0	47.0	43.4	35.4	9.1	9.3
Jet Fuel	2.9	3.6	19.2	22.1	20.0	23.3	28.9	33.5	6.4	0.0
LPG	9.5	14.8	12.1	19.9	24.3	16.0	18.2	19.2	25.4	30.7
Gasoline	21.4	13.9	0.0	10.4	5.7	12.7	8.5	11.3	29.0	23.3
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.5	36.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

When CO_2 emissions of these two scenarios are analyzed, it is seen that the total emissions realize lower than the base scenario due to the impact of the 30% CO_2 emission reduction constraint and the 15%-20% auto efficiency and fuel price change scenario. From 2006 to 2031, emissions follow a similar trend with the 30% reduction scenario but after 2036, they follow a similar path with the 15%-20% auto efficiency and fuel price change scenario.

Regarding fuel types, in both scenarios 3.2.2 and 3.3.2, CO_2 emissions from diesel consumption are lower than the base scenario, due to the increased bio-diesel consumption and reduced diesel consumptions by improved vehicle efficiencies in private cars and saved diesel fuel from the conducted modal shifts. But, as explained in the energy consumption section, diesel emissions increase from scenario 3.2.2 to 3.3.2, due to increased conventional diesel fuel.

Besides, CO_2 emissions from gasoline and LPG consumptions are also decreased due to the consumption of ethanol instead of conventional gasoline, and improved vehicle efficiencies and also reduced private car demand caused by the conducted modal shifts. Besides, it is seen that, compared with the base scenario, the total gasoline emissions are decreased mostly due to the introduction of ethanol fueled private cars (caused by 30% emissions reduction). But, as explained in the energy consumption part, in the last 10 years of the planning horizon, ethanol consumption decreases, and therefore, the emissions resulting from gasoline consumptions increase in both scenarios.

CO_2 emissions from CNG consumption also increased in these scenarios compared to the base scenario, due to the increased demand in intracity buses using CNG fuel. Lastly, due to the impact of 30% CO_2 emission reduction (introduction of liquefied hydrogen) CO_2 emissions resulting from jet fuel consumption are decreased in scenario 2.2.2 compared with the base scenario. But with the impact of and modal shift changes, jet fuel consumption increases again (emissions from liquefied hydrogen increases in both scenarios).

When the trend of CO_2 emissions (Figure 6.24 and 6.25) are analyzed, it is seen that the drop in the emissions level in 2016 is due to the introduction of ethanol caused by the 30% CO_2 reduction, whereas the drop in 2036 is mostly due to decreased diesel fuel consumption caused by the introduction of gaseous hydrogen fueled vehicles in 2036 (as happened in the base scenario and scenarios 2.1.1 and 3.1.1 as well). Then, slight decrease in 2046 stems from the substitution of bio-diesel with the conventional diesel fuel.

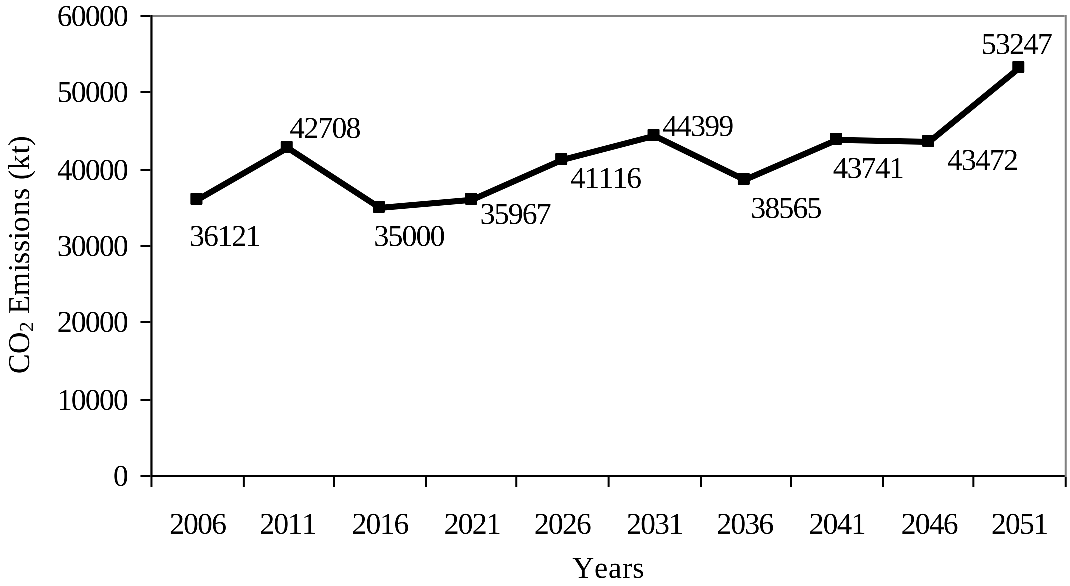

Figure 6.24. CO_2 emissions of the transport sector in scenario 3.2.2.

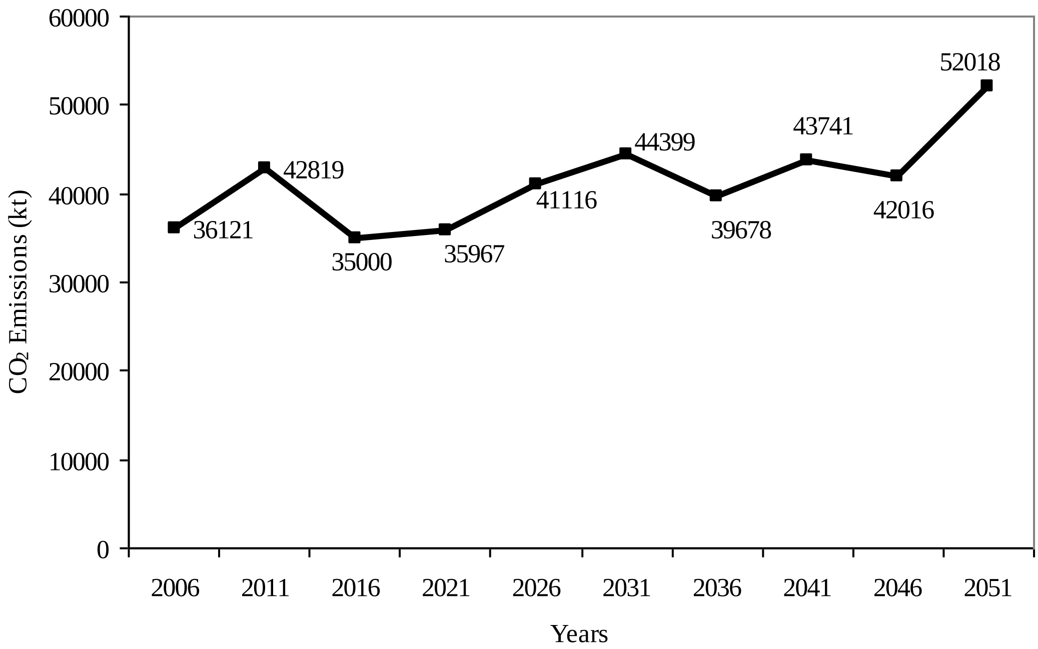

Figure 6.25. CO_2 emissions of the transport sector in scenario 3.3.2.

6.5.4. The 10% and the 20% Modal Shift Scenarios with the 30% CO_2 Emission Reduction Scenario and the 30% Auto Efficiency Improvement and 40% Fuel Price Increase Scenario (3.2.3 and 3.3.3)

The 10% and the 20% modal shift scenarios are integrated with the 30% CO_2 emissions reduction scenario and the 30%-40% auto efficiency and fuel price increase scenario to generate the triple change scenarios 2.2.3 and 2.3.3. The emission constraints, modal shifts and efficiency and fuel price changes are conducted as described in the previous sections.

The results of both scenarios are presented in Tables 6.111-118. Besides, modal energy consumptions by fuel types are presented for these scenarios in Appendix A.

Table 6.111. Energy consumptions by fuel types in scenario 3.2.3 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	6.1	75.0	137.7	164.3	6.4	3.8	4.1	0.0
Diesel	322.6	388.3	340.1	184.3	189.0	174.6	140.3	131.7	42.6	54.7
Electricity	1.1	1.4	8.1	15.6	25.1	35.8	50.1	68.1	80.4	83.3
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	46.3	96.9	245.5	321.6
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	99.2	138.0	187.0	268.8
Jet Fuel	15.2	22.3	64.5	81.8	90.0	121.6	99.1	99.1	0.0	0.0
LPG	54.6	97.5	79.0	129.2	136.5	110.1	134.6	153.6	215.2	292.1
Gasoline	110.2	85.1	0.0	61.3	64.7	56.0	51.4	66.1	149.6	152.1
Ethanol	0.0	0.0	97.5	36.1	56.6	69.2	77.1	82.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	139.3	144.4	144.4	144.4	144.4	213.4	169.5
Total	503.8	598.0	595.2	722.5	844.1	876.0	849.0	983.6	1137.7	1341.9

Table 6.112. Share of fuel types in the total energy consumptions in scenario 3.2.3 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	1.0	10.4	16.3	18.8	0.8	0.4	0.4	0.0
Diesel	64.0	64.9	57.1	25.5	22.4	19.9	16.5	13.4	3.7	4.1
Electricity	0.2	0.2	1.4	2.2	3.0	4.1	5.9	6.9	7.1	6.2
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	5.5	9.9	21.6	24.0
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	11.7	14.0	16.4	20.0
Jet Fuel	3.0	3.7	10.8	11.3	10.7	13.9	11.7	10.1	0.0	0.0
LPG	10.8	16.3	13.3	17.9	16.2	12.6	15.9	15.6	18.9	21.8
Gasoline	21.9	14.2	0.0	8.5	7.7	6.4	6.1	6.7	13.1	11.3
Ethanol	0.0	0.0	16.4	5.0	6.7	7.9	9.1	8.3	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	19.3	17.1	16.5	17.0	14.7	18.8	12.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.113. Energy consumptions by fuel types in scenario 3.3.3 (PJ).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	3.5	6.7	68.1	123.5	123.5	6.9	4.1	4.4	0.0
Diesel	322.6	388.2	322.0	181.7	191.9	205.7	146.8	138.7	51.5	65.6
Electricity	1.1	1.4	9.4	18.1	29.4	42.1	58.1	75.4	79.4	79.5
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	76.2	132.6	286.8	369.7
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	88.2	122.7	180.4	262.8
Jet Fuel	15.2	22.3	96.8	114.5	118.7	145.6	103.5	103.5	0.0	0.0
LPG	54.6	97.8	64.3	110.9	141.2	99.3	119.6	136.3	187.1	260.2
Gasoline	110.2	85.2	0.0	53.6	40.6	41.0	36.6	56.8	144.4	142.5
Ethanol	0.0	0.0	89.5	36.1	56.6	69.2	77.1	82.0	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	125.0	127.4	117.3	127.4	127.4	201.2	162.6
Total	503.8	598.3	588.7	708.0	829.1	843.7	840.3	979.4	1135.2	1343.0

Table 6.114. Share of fuel types in the total energy consumptions in scenario 3.3.3 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.6	1.1	9.6	14.9	14.6	0.8	0.4	0.4	0.0
Diesel	64.0	64.9	54.7	25.7	23.1	24.4	17.5	14.2	4.5	4.9
Electricity	0.2	0.2	1.6	2.6	3.5	5.0	6.9	7.7	7.0	5.9
L.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	9.1	13.5	25.3	27.5
G.Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	10.5	12.5	15.9	19.6
Jet Fuel	3.0	3.7	16.4	16.2	14.3	17.3	12.3	10.6	0.0	0.0
LPG	10.8	16.3	10.9	15.7	17.0	11.8	14.2	13.9	16.5	19.4
Gasoline	21.9	14.2	0.0	7.6	4.9	4.9	4.4	5.8	12.7	10.6
Ethanol	0.0	0.0	15.2	5.1	6.8	8.2	9.2	8.4	0.0	0.0
Bio-Diesel	0.0	0.0	0.0	17.7	15.4	13.9	15.2	13.0	17.7	12.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

In scenarios 3.2.3 and 3.3.3, total diesel consumption (both the conventional and bio-diesel) decreases compared with the base scenario. The reason for this decrease is the deployment of bio-diesel instead of conventional diesel fuel (due to the impact of the 30% CO_2 emissions reduction constraint). Besides, total sum of diesel consumption decreases from scenario 3.2.3 to 3.3.3, due to the increased modal shift from 10% to 20%. In addition, with the contribution of the 15%-20% efficiency improvement and fuel price increase scenario, diesel consumption decreases in private cars. But, consumption of conventional diesel fuel increases from scenario 3.2.3 to 3.3.3 (meaning that the energy system prefers conventional diesel instead of bio-diesel when shifted form scenario 3.2.3 to 3.3.3). Because, the vehicles whose demands are increased with the modal shift (especially ships), mostly use conventional diesel. But the vehicles, whose demands are decreased (especially private cars) mostly use bio-diesel. Thus, although the total diesel consumptions decrease, conventional diesel consumptions increase. In addition, introduction of CNG fueled vehicles in 2021 (due to the impact of the 30%-40% efficiency improvement and fuel price increase scenario) leads to lower diesel consumptions.

Compared with the base scenario, gasoline and LPG consumptions are decreased with use of ethanol in private cars (due to the impact of the 30% CO_2 emissions reduction) and improved auto efficiencies. Besides, among scenarios 3.2.3 and 3.3.3, since the transport demand for private cars decrease (due to modal shift change from 10% to 20%) it leads to lower gasoline and LPG consumptions in scenario 3.3.3. Lastly, due to the mentioned CO_2 emission reduction, electric powered private cars (TC1 and TC2) are introduced to the market after 2016. Ethanol is deployed for gasoline fueled private cars between 2016 and 2041. But, after 2041, gasoline consumptions increase again (since it costs less than ethanol's) due to already satisfied emission constraints in the last 10 years of the planning horizon.

Electricity consumptions are also increased with the increased demands in freight trains, high-speed trains, intracity buses and metros (due to 10% and 20% modal shifts). The introduction of electric powered private cars also contributes to the increase total electricity consumption. CNG consumptions are increased mostly due to the introduction of gaseous hydrogen fueled heavy trucks and tractor trailers. Besides, with the mentioned demand shifts, CNG consumption of intracity buses increase in these two scenarios compared with the base scenario.

Regarding gaseous hydrogen consumptions, it is seen that, with the decreased heavy truck and tractor trailer demands (from 10% and 20% modal shifts) total gaseous hydrogen consumption is also decrease in these two scenarios compared to the base scenario.

Finally, it is seen that, although the total energy consumption of air transport increases, from the base scenario to scenario 3.2.3, jet fuel consumptions are decreased due to the introduction of liquefied hydrogen with the impact of 30% CO_2 emission reduction constraint. But, with the increased airway demand from scenario 3.2.3 to 3.3.3, the total consumptions increase again for both jet fuel and liquefied hydrogen.

Table 6.115. CO_2 emissions by fuel types in scenario 3.2.3 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	340	4206	7727	9216	360	212	229	0
Diesel	23908	28773	25204	13654	14007	12935	10398	9758	3156	4052
Jet Fuel	1055	1542	4471	5666	6239	8430	6866	6866	0	0
LPG	3443	6151	4985	8149	8610	6946	8496	9691	13577	18429
Gasoline	7716	5960	0	4293	4531	3919	3597	4628	10468	10644
L. Hydrogen	0	0	0	0	0	0	2388	4997	12660	16579
Total	36121	42620	35000	35967	41116	41446	32104	36151	40091	49704

Table 6.116. Share of fuel types in the total CO_2 emissions in scenario 3.2.3 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	1.0	11.7	18.8	22.2	1.1	0.6	0.6	0.0
Diesel	66.2	67.5	72.0	38.0	34.1	31.2	32.4	27.0	7.9	8.2
Jet Fuel	2.9	3.6	12.8	15.8	15.2	20.3	21.4	19.0	0.0	0.0
LPG	9.5	14.4	14.2	22.7	20.9	16.8	26.5	26.8	33.9	37.1
Gasoline	21.4	14.0	0.0	11.9	11.0	9.5	11.2	12.8	26.1	21.4
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	7.4	13.8	31.6	33.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.117. CO_2 emissions by fuel types in scenario 3.3.3 (kt).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0	195	376	3821	6930	6930	387	228	246	0
Diesel	23908	28767	23858	13465	14218	15240	10875	10277	3818	4863
Jet Fuel	1055	1542	6707	7931	8222	10090	7172	7172	0	0
LPG	3443	6170	4059	6996	8907	6266	7545	8600	11807	16419
Gasoline	7716	5961	0	3754	2839	2870	2564	3978	10106	9978
L. Hydrogen	0	0	0	0	0	0	3928	6836	14788	19064
Total	36121	42633	35000	35967	41116	41395	32470	37090	40764	50324

Table 6.118. Share of fuel types in the total CO_2 emissions in scenario 3.3.3 (%).

	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
CNG	0.0	0.5	1.1	10.6	16.9	16.7	1.2	0.6	0.6	0.0
Diesel	66.2	67.5	68.2	37.4	34.6	36.8	33.5	27.7	9.4	9.7
Jet Fuel	2.9	3.6	19.2	22.1	20.0	24.4	22.1	19.3	0.0	0.0
LPG	9.5	14.5	11.6	19.5	21.7	15.1	23.2	23.2	29.0	32.6
Gasoline	21.4	14.0	0.0	10.4	6.9	6.9	7.9	10.7	24.8	19.8
L. Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	12.1	18.4	36.3	37.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

When CO_2 emissions of these two scenarios are analyzed, it is seen that the total emissions realize lower than the base scenario due to the impact of 30% CO_2 emission reduction constraint and 30%-40% auto efficiency and fuel price change scenario. From 2006 to 2026, emissions graph follow a similar trend with the 30% reduction scenario but, after 2026, it follow a similar path with 30%-40% auto efficiency and fuel price change scenario.

Regarding fuel types, in both scenarios 3.2.3 and 3.3.3, CO_2 emissions from diesel consumption are lower than the base scenario, due to the increased bio-diesel consumption and reduced diesel consumptions by improved vehicle efficiencies in private cars and saved diesel fuel from the conducted modal shifts. In addition, introduction of CNG fueled heavy trucks and tractor trailers contribute to the savings from diesel consumption. But, as explained in the energy consumption section, diesel emissions increase from scenario 3.2.3 to 3.3.3, due to increased conventional diesel fuel.

Besides, CO_2 emissions from gasoline and LPG consumptions are also decreased due to the consumption of ethanol instead of conventional gasoline, and improved vehicle efficiencies and also reduced private car demand caused by the conducted modal shifts. Besides, it is seen that, compared with the base scenario, the total gasoline emissions are decreased mostly due to the introduction of ethanol fueled private cars (caused by 30% emissions reduction). But, as explained in the energy consumption part, in the last 10 years of the planning horizon, ethanol consumption decreases, and therefore, the emissions resulting from gasoline consumptions increase from scenario 3.2.3 to 3.3.3.

CO_2 emissions from CNG consumption also increased in these scenarios compared to the base scenario, due to the introduction of CNG fueled trucks and increased demand in intracity buses using CNG fuel.

Lastly, it is seen that, although the total energy consumption of air transport increases, from the base scenario to scenario 3.2.3, jet fuel consumptions are decreased due to the introduction of liquefied hydrogen with the impact of 30% CO_2 emission reduction constraint. But, with the increased airway demand from scenario 3.2.3 to 3.3.3, the total consumption increases for both jet fuel and liquefied hydrogen.

When the trend of CO_2 emissions (Figure 6.26 and 6.27) are analyzed, it is seen that the drop in the emissions level in 2016 is due to the introduction of ethanol caused by the 30% CO_2 reduction, whereas the drop in 2036 is mostly due to decreased CNG fuel consumptions caused by the introduction of gaseous hydrogen fueled trucks in 2036. Then the drop in 2046 stems mostly from the substitution of bio-diesel with the conventional diesel fuel.

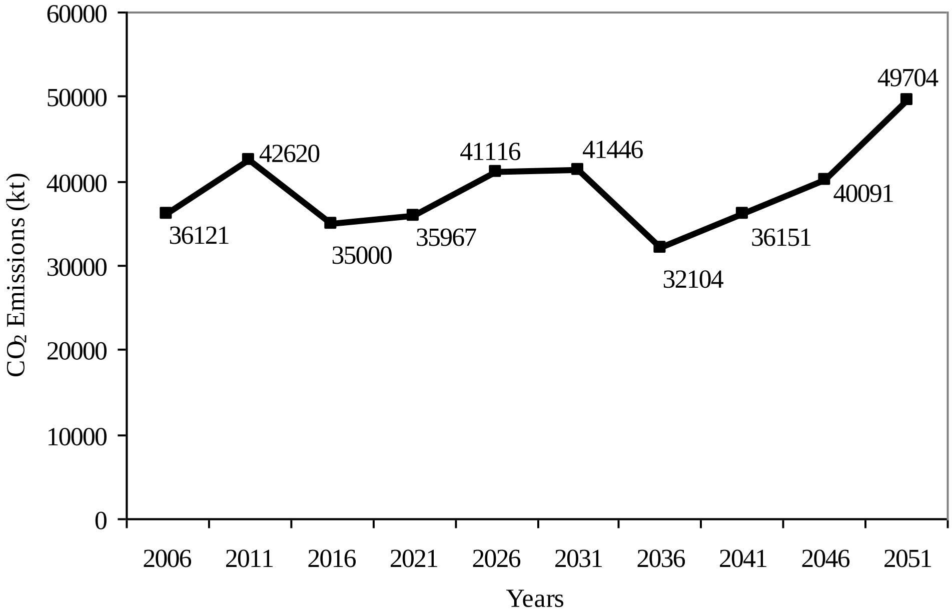

Figure 6.26. CO_2 emissions of the transport sector in scenario 3.2.3.

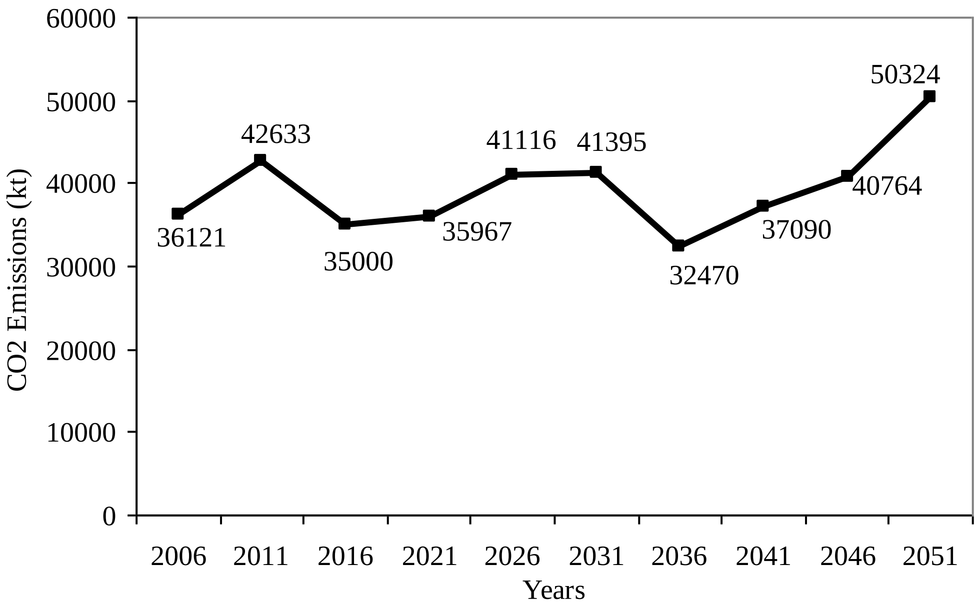

Figure 6.27. CO_2 emissions of the transport sector in scenario 3.3.3.

6.6. The Results of the Scenarios

The results of the scenarios are presented in Table 6.119 with their discounted total system costs and total emission levels from 2006 to 2051. It should be noted that the discounted total system costs are in million pounds with the year 2000 prices. In the table, the scenarios that cost less than the base scenario are noted in bold.

Table 6.119. The total cost and CO_2 emissions of the scenarios.

No.	Total Cost	Emissions									
		2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
1.1.1	883647	36121	43043	45759	51382	58737	63427	56683	62488	68302	76067
2.1.1	886712	36121	42689	38895	43675	49927	53913	48180	53115	58057	64657
3.1.1	900563	36121	42749	35000	35967	41116	44399	39678	43741	47811	53247
1.2.1	**869341**	**36121**	**43043**	**45288**	**50572**	**57036**	**61072**	**55173**	**60977**	**66751**	**74654**
1.3.1	**855232**	**36121**	**43043**	**44745**	**49706**	**55284**	**58692**	**53790**	**59615**	**65190**	**73302**
1.1.2	901121	36121	43043	44628	50738	57899	60698	52046	52079	47676	53700
1.1.3	917427	36121	43043	44470	50855	55145	49149	39013	42599	39609	49233
1.2.2	886764	36121	43043	44435	50180	56229	58430	51157	55631	47064	53425
1.2.3	904384	36121	43043	44526	50728	57188	52820	42338	46823	40761	51673
1.3.2	**872541**	**36121**	**43043**	**44141**	**49539**	**54755**	**56313**	**50345**	**55585**	**46535**	**53187**
1.3.3	889997	36121	43043	44190	50018	55601	54428	45994	51028	41850	52564
2.1.2	903339	36121	42699	38895	43675	49927	53913	42920	47008	43546	53787
2.1.3	919006	36121	42699	38895	43675	44210	44407	34073	37659	39618	49256
3.1.2	908998	36121	42613	35000	35967	41116	44399	35701	43741	43560	53247
3.1.3	922624	36121	42620	35000	35967	41116	42194	31765	35406	39736	49409
2.2.1	**872019**	**36121**	**42689**	**38895**	**43675**	**49927**	**53913**	**48180**	**53115**	**58057**	**63330**
2.3.1	**857524**	**36121**	**42690**	**38895**	**43675**	**49927**	**53913**	**48180**	**53115**	**58057**	**63330**
3.2.1	891689	36121	42840	35100	35967	41116	44399	39678	43741	47811	53247
3.3.1	**878892**	**36121**	**42886**	**35400**	**35967**	**41116**	**44399**	**39678**	**43741**	**47811**	**53247**
2.2.2	888840	36121	42699	38895	43675	49927	53913	42795	48654	43468	53425
2.2.3	906001	36121	42699	38895	43675	46491	48014	37259	41742	40746	51673
2.3.2	**874455**	**36121**	**42700**	**38895**	**43675**	**49927**	**53607**	**43019**	**50984**	**43734**	**53187**
2.3.3	891504	36121	42700	38895	43675	48614	49321	40914	46027	41835	52564
3.2.2	897741	36121	42708	35000	35967	41116	44399	38565	43741	43472	53247
3.2.3	910402	36121	42620	35000	35967	41116	41446	32104	36151	40091	49704
3.3.2	887709	36121	42819	35000	35967	41116	44399	39678	43741	42016	52018
3.3.3	899232	36121	42633	35000	35967	41116	41395	32470	37090	40764	50324

The scenarios studied in this study can be divided in to two groups; the scenarios that can be implemented directly within Turkey and the ones that can be implemented only in line with the developments on the international level. The CO_2 reduction and the modal shift scenarios can be implemented within Turkey with governmental actions or policies, while the fuel price and efficiency scenarios could be implemented tied to the developments on the international level.

It can be observed from the results that all alternative scenarios feature lower emission levels compared to the base scenario. But, most of the alternative scenarios cost more than the base scenario. The general trend indicates that the more emissions are reduced the more it costs; but of course there are exceptions to this generalization.

Of these scenarios, scenario 3.3.1 leads to the least CO_2 emissions but its cost is the closest to that of the base scenario. On the other hand, the scenario with the minimum cost is 1.3.1, which features one of the highest emissions level.

When the overall emission levels are analyzed, the lowest values between 2006 to 2026 are realized by scenarios 3.1.2 and 3.1.3, in 2031 by scenario 3.3.3, from 2036 to 2041 by the scenario 3.1.3 and finally from 2046 to 2051 by scenario 1.1.3. These values are underlined in Table 6.119.

An expected, nevertheless interesting, observation is that in scenarios imposing strict bound on CO_2 emissions (the 15% and the 30% CO_2 reduction scenarios), the model shows a higher preference to investing into cleaner technologies such as electricity (in private cars), CNG (in intracity buses), gaseous hydrogen (in intracity buses) and liquefied hydrogen (in airplanes).

In the 10% and the 20% modal shift scenarios, which impose demand changes in passenger and freight transport modes as explained in the previous chapters, investment decisions are based mostly on satisfying the demands (not on environmental issues). But, some clean technologies are used more in these scenarios.

For example, electricity consumption increases due to the increased freight demand in freight trains and passenger demand in high-speed trains and metros. In addition, CNG is used more due to the demand increase in intracity buses. On the other hand, in these scenarios increased usage of carbon fuels is also observed in some vehicles; for example, with the increased air transport demand, jet fuel (which is a high carbon fuel) consumption is increased while the consumption of gaseous hydrogen (which is a clean fuel) decreases with the shifted demand heavy trucks and tractor trailers to ships. Nevertheless, there are still significant reductions of the related emissions, since the associated modal shifts bring about major reductions in demand (in vehicle kilometers).

In efficiency improvement and fuel price scenarios, due to increased diesel fuel prices, bio-diesel and CNG consumption increases (especially in heavy trucks and tractor trailers). Besides, due to higher gasoline prices, electric powered private cars are introduced to the market. Lastly, since the price of jet fuel is also increased, liquefied hydrogen (which is a cleaner technology) is deployed.

To understand the scenarios’ costs and their emission improvements, a good indicator to generate and track is the division of total savings from CO_2 emissions by the change in discounted total system costs. The results are presented in Table 6.120.

In the table, emissions saved column shows the emissions difference between the base and the corresponding scenario. Since all the scenarios’ emission results are lower than that of the base scenario, all the values in this column are positive. But, regarding the saved cost column, since the scenarios may cost higher or lower than the base scenario, the values in that column can be positive or negative. The values in the ratio column stand for net emission savings by one monetary unit (kt/pound in this study). The positive ratios are especially interesting since they imply savings both in cost and emissions.

Thus, scenarios with positive ratios may be regarded as profitable scenarios. Among these profitable scenarios, the highest ratio is realized for scenario 3.3.1 followed by scenarios 2.3.2 and 1.3.2.

Table 6.120. Emissions and costs savings from the scenarios.

No	Total Cost	Total Emissions	Emissions Saved	Cost Saved	Ratio
1.1.1	883647	562009	0	0	
2.1.1	886712	489229	72780	-3065	-23.7
3.1.1	900563	419830	142179	-16916	-8.4
1.2.1	869341	550687	11322	14306	0.8
1.3.1	855232	539488	22521	28415	0.8
1.1.2	901121	498629	63380	-17474	-3.6
1.1.3	917427	449238	112771	-33780	-3.3
1.2.2	886764	495715	66294	-3117	-21.3
1.2.3	904384	466020	95989	-20737	-4.6
1.3.2	872541	489563	72446	11106	6.5
1.3.3	889997	474836	87173	-6350	-13.7
2.1.2	903339	452490	109518	-19692	-5.5
2.1.3	919006	410615	151394	-35359	-4.3
3.1.2	908998	411465	150544	-25351	-5.9
3.1.3	922624	389336	172673	-38977	-4.4
2.2.1	872019	487902	74107	11628	6.4
2.3.1	857524	487903	74106	26123	2.8
3.2.1	891689	420021	141988	-8042	-17.7
3.3.1	878892	420367	141642	4755	29.8
2.2.2	888840	453571	108438	-5193	-20.9
2.2.3	906001	427315	134693	-22354	-6.0
2.3.2	874455	455849	106160	9192	11.5
2.3.3	891504	440666	121343	-7857	-15.4
3.2.2	897741	414337	147672	-14094	-10.5
3.2.3	910402	390322	171687	-26755	-6.4
3.3.2	887709	412876	149133	-4062	-36.7
3.3.3	899232	392883	169126	-15585	-10.9

Regarding the scenarios that costs higher than the base scenario, since the ratios are negative, absolute values should be considered to find the best scenario. Thus, when the results are analyzed, it is seen that among these scenarios, the best scenario is 3.3.2 followed by 2.1.1 and 1.2.2. All the mentioned scenarios are sorted with respect to their ratios and they are presented in Table 6.119.

Table 6.121. Emissions and costs savings from the scenarios (sorted).

No	Total Cost	Total Emissions	Emissions Saved	Cost Saved	Ratio
3.3.1	878892	420367	141642	4755	29.8
2.3.2	874455	455849	106160	9192	11.5
1.3.2	872541	489563	72446	11106	6.5
2.2.1	872019	487902	74107	11628	6.4
2.3.1	857524	487903	74106	26123	2.8
1.3.1	855232	539488	22521	28415	0.8
1.2.1	869341	550687	11322	14306	0.8
1.1.1	883647	562009	0	0	0
1.1.3	917427	449238	112771	-33780	-3.3
1.1.2	901121	498629	63380	-17474	-3.6
2.1.3	919006	410615	151394	-35359	-4.3
3.1.3	922624	389336	172673	-38977	-4.4
1.2.3	904384	466020	95989	-20737	-4.6
2.1.2	903339	452490	109518	-19692	-5.6
3.1.2	908998	411465	150544	-25351	-5.9
2.2.3	906001	427315	134693	-22354	-6.0
3.2.3	910402	390322	171687	-26755	-6.4
3.1.1	900563	419830	142179	-16916	-8.4
3.2.2	897741	414337	147672	-14094	-10.5
3.3.3	899232	392883	169126	-15585	-10.9
1.3.3	889997	474836	87173	-6350	-13.7
2.3.3	891504	440666	121343	-7857	-15.4
3.2.1	891689	420021	141988	-8042	-17.7
2.2.2	888840	453571	108438	-5193	-20.9
1.2.2	886764	495715	66294	-3117	-21.3
2.1.1	886712	489229	72780	-3065	-23.7
3.3.2	887709	412876	149133	-4062	-36.7

Regarding all these scenarios, excluding the efficiency and fuel price scenario which can be implemented only in case of global improvements and changes (namely scenarios with numbers ending with 2 and 3), the best scenario, among the scenarios with system cost lower than the base scenario, is 3.3.1. Besides, scenarios 2.2.1, 2.3.1, 1.3.1 and 1.2.1 can be implemented. Likewise, regarding the scenarios with system costs higher than the base scenario, the best one is 2.1.1 followed by 3.2.1 and 3.1.1.

In addition, Figure 6.28-30 present the emission trends of the alternative scenarios with that of the base scenario. For better analysis the figures are presented in three groups; the base scenario with the unary case scenarios which feature a single factor change, the base scenario with the binary case scenarios which feature two factor changes, and the base scenario with the ternary case scenarios which feature triple factor changes.

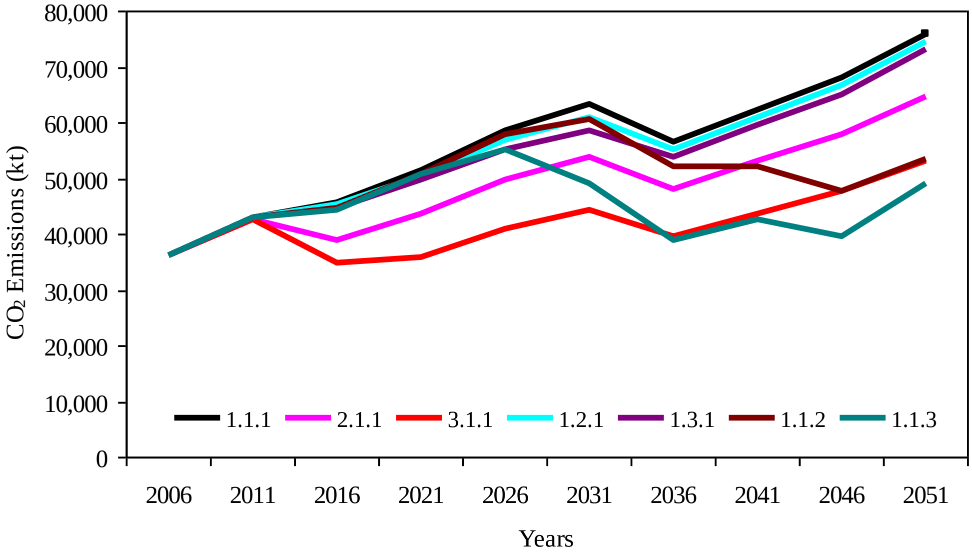

Figure 6.28. CO_2 emissions of the base and the unary case scenarios.

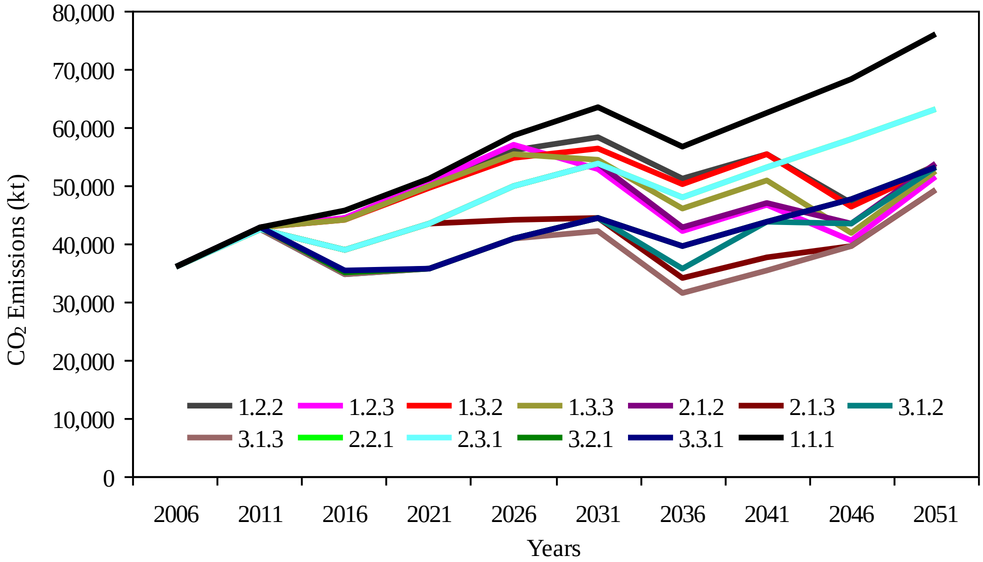

Figure 6.29. CO_2 emissions of the base and the binary case scenarios.

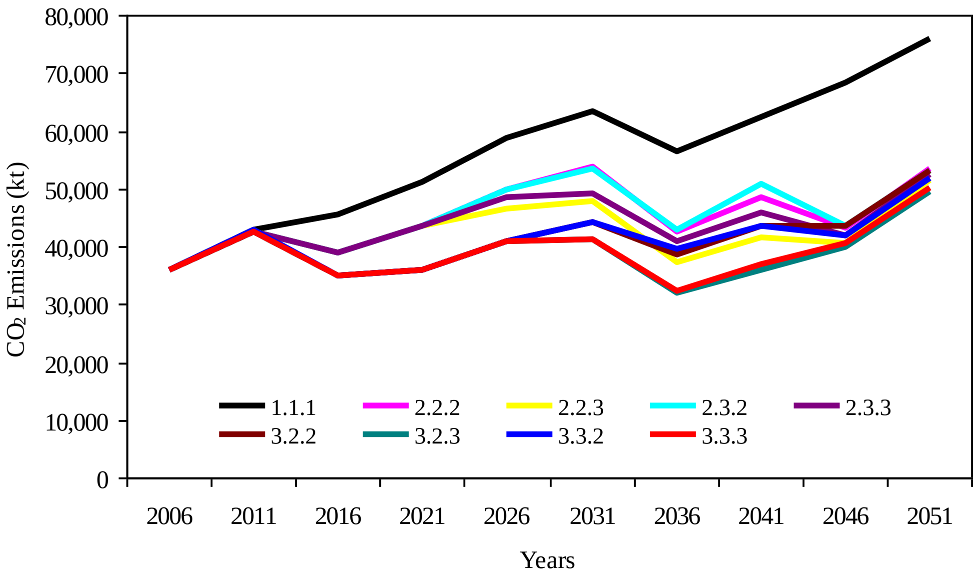

Figure 6.30. CO_2 emissions of the base and the ternary case scenarios.

Regarding the entire energy system, it is also important to see the effects of these scenarios on CO_2 emissions from the transport sector and the energy sector sector. Therefore Table 6.122 is created to analyze these two intercorelated sectors. It should be noted that energy sector covers both the electricity generation and hydrogen production processes. Thus, emissions from energy sector depend on both electric powered and hydrogen fueled vehicles. It should also be noted that the emissions from the energy sector does not depend solely on the transport activities. Since energy is consumed in all demand sectors, the changes imposed by the scenarios may also affect the activities in other sector such as industial, residential etc.

It can be seen that in CO_2 emission reduction scenarios, savings from the emissions in the transport sector are much more than the increase in the emissions from energy sector. Because, bio-diesel and ethanol are heavily used instead of conventional fuels, the savings are more than the increase in the energy sector related CO_2 emissions.

In 10% and 20% modal shift scenarios, CO_2 emissions from both the transport and the energy sector decrease. Although CO_2 emissions resulting from electricity consumption increase in these scenarios, due to reduced demands of hydrogen fueled motor vehicles (trucks etc.), total emissions from energy sector decrease compared with the base scenario.

In auto efficiency and fuel price scenarios, savings from the transport sector is less than the increase in the emissions from the energy sector. In these scenarios, since the prices of conventional fuels are increased for the entire energy system, electricity and hydrogen are used as alternatives for conventional fuel types (in all sectors) leading to higher emissions resulting from the energy sector.

Among the scenario combinations, 3.1.1, 2.2.1, 3.2.1, and 3.3.1 are the best scenarios due to higher emission savings provided by CO_2 reduction and modal shift scenarios. These scenarios are applicable regarding the total environmental impacts.

As expected, the auto efficiency improvement and fuel price change scenarios (either 15%-20% or 30%-40%) are common among the scenarios whose emission savings are negative. These scenarios are not viable regarding the total CO_2 emissions from the transport and the energy sector. Considering the scenarios with negative savings, the worst ones are 1.3.3, 1.2.3, 1.3.2, and 1.2.2.

Finally, as mentioned before in the results of the base scenario, the share of sectors in total CO_2 emissions and energy consumptions are presented for all alternative scenarios in Appendix B.

Table 6.122. CO_2 emissions from the transport and the energy sector by scenarios.

Scenario	Sector	Total Emissions (kt)	% Change	Savings	Net Savings
BASE	Energy	4799057	0.0	0	0
BASE	Transport	562009	0.0	0	
2.1.1	Energy	4811371	0.3	-12315	60465
2.1.1	Transport	489229	-12.9	72780	
3.1.1	Energy	4857685	1.2	-58628	83551
3.1.1	Transport	419830	-25.3	142179	
1.2.1	Energy	4794267	-0.1	4790	16112
1.2.1	Transport	550687	-2.0	11322	
1.3.1	Energy	4789039	-0.2	10018	32538
1.3.1	Transport	539488	-4.0	22521	
1.1.2	Energy	4885873	1.8	-86816	-23523
1.1.2	Transport	498715	-11.3	63294	
1.1.3	Energy	4921065	2.5	-122009	-9238
1.1.3	Transport	449238	-20.1	112771	
1.2.2	Energy	4900789	2.1	-101733	-35439
1.2.2	Transport	495715	-11.8	66294	
1.2.3	Energy	4944893	3.0	-145836	-49847
1.2.3	Transport	466020	-17.1	95989	
1.3.2	Energy	4914732	2.4	-115675	-43229
1.3.2	Transport	489563	-12.9	72446	
1.3.3	Energy	4955837	3.3	-156780	-69608
1.3.3	Transport	474836	-15.5	87173	
2.1.2	Energy	4897118	2.0	-98061	11457
2.1.2	Transport	452490	-19.5	109518	
2.1.3	Energy	4921013	2.5	-121956	29438
2.1.3	Transport	410615	-26.9	151394	
3.1.2	Energy	4894293	2.0	-95236	55308
3.1.2	Transport	411465	-26.8	150544	
3.1.3	Energy	4924697	2.6	-125640	47032
3.1.3	Transport	389336	-30.7	172673	
2.2.1	Energy	4796455	-0.1	2601	75381
2.2.1	Transport	489229	-12.9	72780	
2.3.1	Energy	4812079	0.3	-13022	59757
2.3.1	Transport	489230	-12.9	72779	
3.2.1	Energy	4866714	1.4	-67658	74330
3.2.1	Transport	420021	-25.3	141988	
3.3.1	Energy	4866944	1.4	-67887	73754
3.3.1	Transport	420367	-25.2	141642	
2.2.2	Energy	4910573	2.3	-111516	-3079
2.2.2	Transport	453571	-19.3	108438	
2.2.3	Energy	4948073	3.1	-149016	-14323
2.2.3	Transport	427315	-24.0	134693	
2.3.2	Energy	4922345	2.6	-123289	-17129
2.3.2	Transport	455849	-18.9	106160	
2.3.3	Energy	4956426	3.3	-157369	-36026
2.3.3	Transport	440666	-21.6	121343	
3.2.2	Energy	4911145	2.3	-112089	35583
3.2.2	Transport	414337	-26.3	147672	
3.2.3	Energy	4960823	3.4	-161766	9920
3.2.3	Transport	390322	-30.5	171687	
3.3.2	Energy	4925015	2.6	-125958	23175
3.3.2	Transport	412876	-26.5	149133	
3.3.3	Energy	4991733	4.0	-192676	-23550
3.3.3	Transport	392883	-30.1	169126	

7. CONCLUSION

Since global warming is one of the main concerns on the planet, some measures are taken by all the countries. As described in the introduction part, one of these measures is the Kyoto Protocol whose implementation initiated in 2005. Turkey ratified the Kyoto Protocol in 2009; but, since Turkey was not party to the UNFCCC, while the negotiations for the protocol were carried on, she did not commit any emission reduction targets like other members. Nevertheless, planning for emission reductions and policies regarding setting targets is still a very important national issue.

Therefore, Turkey should be prepared and ready for setting CO_2 mitigation targets and make some alternative policies or strategies regarding this kind of potential commitments. Related priorities and policy decisions depend on economic and social structure of a country, as well as the country's status on the international platform.

In this study, the main objective is to analyze the energy supply demand balance and CO_2 emissions of Turkey from the transport sector by MARKAL energy system modeling. The transport sector is divided in to 23 sub-modes, namely vehicle types, and the analysis is conducted on this level. This enabled the analysis of both the whole transport sector and of specific transport modes.

The results show that in the base scenario, different from the existing technologies, gaseous hydrogen fueled heavy trucks and tractor trailers are introduced in the market instead of diesel fueled ones. Besides, after 2016, electricity is deployed among intercity buses, intracity buses and taxies. Lastly, liquefied hydrogen fueled airplanes are used in 2051. Since the base scenario does not include any specific constraints or bounds, the energy system invest in new technologies regarding only their costs. Thus, high-cost new technologies like liquefied hydrogen fueled airplanes are introduced in the market very late in the planning horizon. But, since the alternative scenarios impose constraints or changes (such as emission reduction constraints or modal shifts), investment decisions are based not only on their costs but also on the system-wide restrictions or decisions.

In the 15% and 30% CO_2 emission reduction scenarios, since strict emission upper bounds are applied, the model invests in cleaner but also more costly technologies. In these scenarios, ethanol (instead of gasoline) and bio-diesel (instead of conventional diesel), which are regarded as zero carbon fuels, are deployed to satisfy the emission bounds. Besides, gaseous hydrogen is used in intercity and intracity buses in the last years of the planning horizon. Electricity fueled private cars are also introduced in the market after 2016. Lastly, liquefied hydrogen is used more in air transport, since it is a cleaner form of fuel compared to the conventional jet fuel.

In the 10% and 20% modal shift scenarios, the investment decisions are made regarding the travel demand changes in the transport modes and sub-modes. In these scenarios, the gaseous hydrogen fuel consumption decreases due to the reduced travel demand in heavy trucks, tractor trailers and light truck. On the other hand, compared to the base scenario, since the travel demands of ships, freight trains, high-speed trains and metro increase in these scenarios, diesel and electricity consumptions also increase in these sub-modes. Lastly, in these scenarios, due to the increased travel demand in the air transport sector, liquefied hydrogen fueled airplanes are deployed earlier compared to the base scenario.

In the 15%-30% auto efficiency improvement and 20%-40% fuel price change scenarios, bio-diesel consumption is deployed instead of conventional diesel, due to the increased diesel fuel prices. Besides, CNG fueled heavy trucks and tractor trailers are introduced in the market after 2020s. Regarding the private cars, since the conventional fuel prices are increased, electric powered private cars are used in these scenarios. Lastly, due to the increased jet fuel prices, liquefied hydrogen is deployed earlier in these scenarios.

In the binary and ternary case combinations of these scenarios, it is seen that each scenario contributes to the total emissions and total system cost by their scenario specific investment decisions and technology selection. Thus, in these scenarios, the above mentioned scenario specific vehicle and fuel types are also observed.

The results show that, although most of the scenarios cost higher than the base scenario, some scenarios cost less. It is seen that modal shift scenarios decrease the total system cost but do not provide much emission savings. On the other hand, CO_2 reduction scenario and auto efficiency with fuel price change scenario reduce the total emissions much more than the modal shift scenarios, but they have a negative impact on the total system cost.

Regarding the scenarios that cost less than the base scenario (low cost scenarios), it is seen that all theses scenarios are dominated by the 10% and 20% modal shift scenarios. The reason for this is that the modal shift scenarios feature more efficient and economic transport modes. For example, regarding freight transport, the travel demand is shifted from heavy trucks, tractor trailers and light trucks to more efficient and economic sub-modes such as trains and ships. Thus, the total costs decrease due to reduced investment and fuel costs. But, it should be noted that in these scenarios, additional infrastructure investments (ports, terminals etc.) are not considered, and as a consequence they costs are lower than the base scenario.

Among these low cost scenarios, scenario 3.3.1 ranks the first. It features the impact of both the 20% modal shift and the 30% emission reduction. Thus, although it costs higher than other low cost scenarios, the modal shift and the emission reduction impacts make scenario 3.3.1 the most feasible choice. Scenarios 2.3.2 and 1.3.2, which follow scenario 3.3.1, feature the impact of 20% modal shift together with the savings from the 15% emission reduction and the 15%-20% auto efficiency and fuel price scenarios. Likewise, although scenarios 2.3.2 and 1.3.2 cost higher than scenario 1.3.1, they rank as the second and the third best due to their high emission savings.

Regarding the scenarios that cost higher than the base scenario (high cost scenarios), scenario 3.3.2 gives the highest ratio. It is followed by the scenarios 2.1.1 and 1.2.2. It can be easily seen that scenario 3.3.2 is similar to scenario 3.3.1 (which is the best scenario among the low cost scenarios). Scenario 3.3.2 features the impact of the 20% modal shift, the 30% emission reduction and the 15%-20% auto efficiency and fuel price scenarios. Since the extra costs of the 30% emission reduction and 15%-20% auto efficiency and fuel price scenarios are balanced with the 20% modal shift scenario, the amount of saved emissions make scenario 3.3.2 the most feasible alternative among the high cost scenarios. In scenario 2.1.1, although the total system cost is increased, due to high relative savings from the emissions, it is ranked as the second best choice among the high cost scenarios. Lastly, scenario 1.2.2 features the impact of 10% modal shift together with the 15%-20% auto efficiency and fuel price scenarios. In this scenario, the cost savings from the 10% modal shift scenario balances the cost of the 15%-20% efficiency and fuel price scenario, and together with the saved emissions, scenario 1.2.2 ranks the third best alternative scenario.

As discussed in the previous chapter, in general, the cost of scenarios depends on the degree of the targeted CO_2 reduction level. If the targeted emission levels are slightly lower than the base scenario, then this option does not cost high, whereas, if the targeted levels are much more lower than the base scenario, then the total system cost can grow up by 40 billion Pounds over the planning horizon which means a 4.4% increase.

Since Turkey is a developing country, the transport demand is expected to grow fast in the short and the long term. To overcome this demand increase, the studied scenarios, can be implemented provided that both the needed transport infrastructure and policy changes are completed.

If it is foreseen that Turkey, will not commit herself to significant CO_2 mitigation targets, the scenarios that cost less can be considered. Modal shift scenarios can be given as examples to this strategy as discussed in the previous section

Regarding the modal shift scenarios, the infrastructure investments should be completed for the necessary transport network. Furthermore, after these investments, appropriate policies should be implemented to direct people towards the targeted modal shifts. For example, by constructing additional high-speed train lines people can be automatically directed from private car or intercity buses. Additionally, in cities, CNG fueled buses or electricity driven transport vehicles (such as metros, trams etc) can be disseminated (of course with a well organized network and infrastructure) for public transport purposes. With these investments, CO_2 emissions can be reduced as realized in scenarios 1.2.1 and 1.3.1.

But, if it is expected that Turkey will need to commit herself to major reductions in her CO_2 emissions in the near future, than more stringent scenarios that cost higher, like the 15% and the 30% emissions reduction policies should be implemented.

Regarding CO_2 emission reduction scenarios, the scenario analysis indicates that governments should incentivize vehicles with cleaner technologies and reduce the taxes on these vehicles. Moreover, the policies should be implemented to widen the use of cleaner fuel types such as bio-diesel and ethanol. For example, as mentioned in CO_2 reduction scenarios, electric powered private cars can be incentivized in Turkey, by applying lower tax rates compared with the private cars using fossil fuels.

Finally, scenarios featuring efficiency improvement and fuel price increase can be implemented provided that the mentioned developments are realized on the international platform.

In conclusion, all policy models require improvement and update of the data. The model data in this study can be used as basis for the transport sector, but as time passes, the data for the future years should be updated so that a more precise and realistic analysis can be conducted. As the information technology develops, the technologies and devices are also developed by which relevant and accurate data can be collected for the transport sector. The extension to this study can be the implementation of accurately collected data to the model. Besides, for a more detailed analysis the number of modes can be improved by adding some missing modes (such as vehicles used in agriculture, motorbikes, commercial cars etc.) to the study. Lastly, in the future studies, some constraints can be added to the model in order to obtain smoother fuel switches (i.e. from gasoline to ethanol) between time periods.

APPENDIX A: MODAL ENERGY CONSUMPTIONS BY FUEL TYPES

Table A.1. Modal energy consumptions by fuel types in the base scenario (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
BASE	TCNGBUS	TB2	0	3.47	5.84	6.2	4.86	5.5	5.8	3.39	4.03	0
BASE	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
BASE	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.18	2.59	3.02	3.59	4.26	5.06
BASE	TDIE	TSDY	0.01	0.02	0.04	0.06	0.09	0.12	0.18	0.24	0.32	0.43
BASE	TDIE	TSKT	0.03	0.04	0.07	0.11	0.16	0.23	0.34	0.45	0.6	0.81
BASE	TDIE	TSKY	0.63	1.02	1.64	2.64	3.84	5.6	8.18	10.89	14.53	19.4
BASE	TDIE	TSTK	0.48	0.78	1.26	2.02	2.97	4.37	6.42	8.59	11.5	15.39
BASE	TDIEBUS	TB1	37.39	41.25	38.07	34.54	30.23	23.28	17.55	10.81	5.41	2.91
BASE	TDIEBUS	TB2	22.35	23.26	21.95	19.31	16.92	13.05	7.41	5.85	3.44	0
BASE	TDIEBUS	TB3	21.03	24.32	28.34	32.99	34.45	40.42	47.35	54.74	63.79	74.83
BASE	TDIECAR	TC1	5.36	14	17.45	17.45	18.27	12.36	13.72	16.26	15.43	11.11
BASE	TDIECAR	TC2	10.28	26.86	32.52	32.52	34.11	22.77	26.33	31.19	29.61	21.33
BASE	TDIECAR	TC3	1.47	3.84	4.78	4.78	5.01	3.39	3.76	4.46	4.23	3.05
BASE	TDIECAR	TC4	0.37	0.97	1.21	1.21	1.27	0.86	0.96	1.13	1.07	0.77
BASE	TDIECAR	TCX	0.15	0.18	0.16	0.12	0.15	0.07	0.08	0	0	0
BASE	TDIEHGV	TH1	153.28	140.72	124.54	119.48	116.31	114.48	46.35	34.72	23.26	11.69
BASE	TDIEHGV	TH2	34.91	75.89	73.64	101.22	158.01	195.49	109.57	99.95	83.41	52.94
BASE	TDIELGV	TL	25.58	26.16	23.37	20.23	17.36	13.17	11.04	8.65	6.06	2.96
BASE	TDIERAIL	TRF	4.43	4.76	4.96	4.83	4.39	4.1	3.52	2.59	2.67	2.94
BASE	TDIERAIL	TRM	2.37	2.38	2.08	1.91	1.66	1.44	1.21	0.91	0.81	0.82
BASE	TELC	TB1	0	0	0.68	2.82	5.19	7.79	10.6	13.9	16.53	18.54
BASE	TELC	TB2	0	0	0.91	2.63	5.47	8.42	12.21	16.24	20.02	26.03
BASE	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
BASE	TELC	TL	0	0	1.33	2.74	3.77	4.88	5.92	7.1	8.38	9.79
BASE	TELC	TRF	0.25	0.27	0.39	0.67	0.99	1.37	1.82	2.54	2.8	3.07
BASE	TELC	TRH	0	0.13	0.25	0.51	0.8	1.28	2.02	2.56	3.22	4.06
BASE	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
BASE	TELC	TRMET	0.17	0.3	0.42	0.5	0.57	0.65	0.72	0.8	0.94	1.04
BASE	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
BASE	THDGAIR	TA	0	0	0	0	0	0	0	0	0	69.09
BASE	THDGHGV	TH1	0	0	0	0	0	0	34.09	39.97	45.55	51.19
BASE	THDGHGV	TH2	0	0	0	0	0	0	76.13	113.36	162.23	229.96
BASE	TJETAIR	TA	15.22	22.25	32.24	49.06	61.42	94.04	110.27	151.11	171.02	171.02
BASE	TLPGCAR	TC1	16.57	31.14	33.6	34.12	34.12	26.57	31.18	30.66	30.66	24.73
BASE	TLPGCAR	TC2	24.52	46.11	56.01	69.78	89.42	105.27	130.1	152.91	196.23	238.12
BASE	TLPGCAR	TC3	5.45	10.24	12.44	15.5	19.87	23.39	28.91	33.98	43.61	52.92
BASE	TLPGCAR	TC4	1.2	2.41	2.59	2.63	2.63	1.92	2.26	2.22	2.22	1.79
BASE	TLPGCAR	TCX	6.82	7.57	8.57	8.57	7.62	5.06	2.96	1.76	0	0
BASE	TPETCAR	TC1	39.21	32.03	42.91	57.82	70.22	82.45	91.76	107.11	143.09	193.05
BASE	TPETCAR	TC2	55.89	45.65	55.19	64.03	69.41	70.76	76.08	89.37	92.89	106.06
BASE	TPETCAR	TC3	12.04	9.83	11.89	13.79	14.95	15.24	16.39	19.25	20	22.84
BASE	TPETCAR	TC4	3.1	2.53	3.42	4.55	5.8	7.21	8.33	10.23	12.54	15.75

Table A.2. Modal energy consumptions by fuel types in scenario 2.1.1 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
2.1.1	TCNGBUS	TB2	0	3.47	5.4	6.36	4.71	5.33	6.09	3.49	3.78	0
2.1.1	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
2.1.1	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
2.1.1	TDIE	TSDY	0.01	0.02	0.04	0.06	0.09	0.12	0.18	0.24	0.32	0.43
2.1.1	TDIE	TSKT	0.03	0.04	0.07	0.11	0.16	0.23	0.34	0.45	0.6	0.81
2.1.1	TDIE	TSKY	0.63	1.02	1.64	2.64	3.84	5.6	8.18	10.89	14.53	19.4
2.1.1	TDIE	TSTK	0.48	0.78	1.26	2.02	2.97	4.37	6.42	8.59	11.5	15.39
2.1.1	TDIEBUS	TB1	37.39	41.25	38.07	34.54	29.43	23.64	17.65	10.74	5.53	2.91
2.1.1	TDIEBUS	TB2	22.35	23.26	20.26	19.25	17.15	12.62	7.5	5.93	3.28	0
2.1.1	TDIEBUS	TB3	21.03	24.32	28.34	32.99	34.45	40.42	47.35	54.74	63.79	74.83
2.1.1	TDIECAR	TC1	5.36	14	16.95	16.95	17.78	11.87	13.72	16.26	15.43	11.11
2.1.1	TDIECAR	TC2	10.28	26.86	32.52	32.52	34.11	22.77	26.33	31.19	29.61	21.33
2.1.1	TDIECAR	TC3	1.47	3.84	4.65	4.65	4.87	3.25	3.76	4.46	4.23	3.05
2.1.1	TDIECAR	TC4	0.37	0.97	1.21	1.21	1.27	0.86	0.96	1.13	1.07	0.77
2.1.1	TDIECAR	TCX	0.15	0.18	0.16	0.12	0.15	0.07	0.08	0	0	0
2.1.1	TDIEHGV	TH1	153.28	140.72	122.04	119.48	115.82	110.69	46.94	35.31	23.56	11.69
2.1.1	TDIEHGV	TH2	34.91	75.89	65.81	102.54	158.47	197.16	105.63	99.95	83.41	52.94
2.1.1	TDIELGV	TL	25.58	26.16	23.07	19.52	15.81	13.55	11.31	8.87	5.64	2.96
2.1.1	TDIERAIL	TRF	4.43	4.76	4.96	4.83	4.39	4.07	3.54	2.59	2.67	2.94
2.1.1	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
2.1.1	TELC	TB1	0	0	0.68	2.82	5.19	7.79	10.6	13.9	16.53	18.54
2.1.1	TELC	TB2	0	0	0.91	2.63	5.47	8.42	12.21	16.24	20.02	26.03
2.1.1	TELC	TC1	0	0	1.13	3.45	3.45	3.45	9.33	7.01	7.01	7.01
2.1.1	TELC	TC2	0	0	0	3.91	3.91	3.91	13.67	9.76	9.76	9.76
2.1.1	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
2.1.1	TELC	TL	0	0	1.33	2.74	3.77	4.88	5.92	7.1	8.38	9.79
2.1.1	TELC	TRF	0.25	0.27	0.39	0.67	0.99	1.37	1.82	2.54	2.8	3.07
2.1.1	TELC	TRH	0	0.13	0.25	0.51	0.8	1.28	2.02	2.56	3.22	4.06
2.1.1	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
2.1.1	TELC	TRMET	0.17	0.3	0.42	0.5	0.57	0.65	0.72	0.8	0.94	1.04
2.1.1	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
2.1.1	THDGAIR	TA	0	0	0	0	0	0	0	0	0	69.09
2.1.1	THDGHGV	TH1	0	0	0	0	0	0	34.09	39.97	45.55	51.19
2.1.1	THDGHGV	TH2	0	0	0	0	0	0	76.13	113.36	162.23	229.96
2.1.1	TJETAIR	TA	15.22	22.25	32.24	47.38	61.42	90.25	108.06	148.91	171.02	171.02
2.1.1	TLPGCAR	TC1	16.57	31.14	33.6	34.12	34.12	26.57	31.18	30.66	30.66	24.73
2.1.1	TLPGCAR	TC2	24.52	46.11	56.01	56.01	75.64	56.74	46.84	83.43	126.74	203.39
2.1.1	TLPGCAR	TC3	5.45	10.24	12.44	15.5	19.87	9.62	15.14	20.21	29.84	52.92
2.1.1	TLPGCAR	TC4	1.2	2.41	2.59	2.63	2.63	1.92	2.26	2.22	2.22	1.79
2.1.1	TLPGCAR	TCX	6.82	7.57	8.57	8.57	7.62	5.06	2.96	1.76	0	0
2.1.1	TPETCAR	TC1	39.21	30.23	36.92	43.12	55.53	69.55	62.87	91.12	110.31	160.26
2.1.1	TPETCAR	TC2	55.89	43.09	52.63	61.47	66.85	93.87	99.19	112.47	115.99	106.06
2.1.1	TPETCAR	TC3	12.04	9.28	11.33	13.24	14.4	23.01	24.15	27.01	27.77	22.84
2.1.1	TPETCAR	TC4	3.1	2.39	3.22	4.35	5.28	6.33	7.03	8.2	10.86	14.57

Table A.3. Modal energy consumptions by fuel types in scenario 3.1.1 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
3.1.1	TCNGBUS	TB2	0	3.47	5.4	6.36	5.03	5.09	5.99	3.54	3.7	0
3.1.1	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
3.1.1	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
3.1.1	TDIE	TSDY	0.01	0.02	0.04	0.06	0.09	0.12	0.18	0.24	0.32	0.43
3.1.1	TDIE	TSKT	0.03	0.04	0.07	0.11	0.16	0.23	0.34	0.45	0.6	0.81
3.1.1	TDIE	TSKY	0.63	1.02	1.64	2.64	3.84	5.6	8.18	10.89	14.53	19.4
3.1.1	TDIE	TSTK	0.48	0.78	1.26	2.02	2.97	4.37	6.42	8.59	11.5	15.39
3.1.1	TDIEBUS	TB1	37.39	41.25	38.07	34.54	29.57	23.57	17.71	10.81	5.41	2.91
3.1.1	TDIEBUS	TB2	22.35	23.26	20.26	19.25	17.15	12.62	7.5	5.93	3.28	0
3.1.1	TDIEBUS	TB3	21.03	24.32	25.42	30.84	35.36	39.82	47.07	55.22	62.88	74.12
3.1.1	TDIECAR	TC1	5.36	13.63	16.58	14.73	17.41	11.87	13.72	16.26	15.43	11.11
3.1.1	TDIECAR	TC2	10.28	26.35	30.96	27.4	38.31	23.17	26.16	31.01	31.01	21.6
3.1.1	TDIECAR	TC3	1.47	3.74	4.55	4.04	4.77	3.25	3.76	4.46	4.23	3.05
3.1.1	TDIECAR	TC4	0.37	0.95	1.16	1.16	1.21	0.83	0.96	1.13	1.07	0.77
3.1.1	TDIECAR	TCX	0.15	0.18	0.14	0.11	0.13	0.08	0.08	0	0	0
3.1.1	TDIEHGV	TH1	153.28	140.72	122.04	119.48	115.82	109.8	47.24	35.61	23.02	11.15
3.1.1	TDIEHGV	TH2	34.91	75.89	65.81	102.54	159.34	196.82	105.63	99.95	83.41	52.94
3.1.1	TDIELGV	TL	25.58	26.16	20.57	17.8	16.04	14.04	10.72	8.45	5.92	3.11
3.1.1	TDIERAIL	TRF	4.43	4.76	4.96	4.83	4.39	4.07	3.54	2.59	2.67	2.94
3.1.1	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
3.1.1	TELC	TB1	0	0	0.68	2.82	5.19	7.79	10.6	13.9	16.53	18.49
3.1.1	TELC	TB2	0	0	0.91	2.63	5.47	8.42	12.21	16.24	15.57	10.06
3.1.1	TELC	TC1	0	0	1.13	1.13	1.13	1.13	7.31	7.31	7.31	7.31
3.1.1	TELC	TC2	0	0	1.81	1.81	1.81	1.81	20.02	22.03	22.03	22.03
3.1.1	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
3.1.1	TELC	TL	0	0	1.33	2.74	3.77	4.88	5.92	7.1	8.38	9.79
3.1.1	TELC	TRF	0.25	0.27	0.39	0.67	0.99	1.37	1.82	2.54	2.8	3.07
3.1.1	TELC	TRH	0	0.13	0.25	0.51	0.8	1.28	2.02	2.56	3.22	4.06
3.1.1	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
3.1.1	TELC	TRMET	0.17	0.3	0.42	0.5	0.57	0.65	0.72	0.8	0.94	1.04
3.1.1	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
3.1.1	THDGAIR	TA	0	0	0	0	0	0	0	0	72.46	141.55
3.1.1	THDGBUS	TB1	0	0	0	0	0	0	0	0	0	0.07
3.1.1	THDGBUS	TB2	0	0	0	0	0	0	0	0	5.97	21.45
3.1.1	THDGHGV	TH1	0	0	0	0	0	0	34.09	39.97	45.55	51.19
3.1.1	THDGHGV	TH2	0	0	0	0	0	0	76.13	113.36	162.23	229.96
3.1.1	TJETAIR	TA	15.22	22.25	32.24	47.38	61.42	90.25	108.06	148.91	110.35	110.35
3.1.1	TLPGCAR	TC1	16.57	31.9	29.63	49.96	61.53	29.63	30.58	30.58	30.58	30.58
3.1.1	TLPGCAR	TC2	24.52	47.22	43.85	73.96	91.08	90.22	46.37	63	106.88	160.86
3.1.1	TLPGCAR	TC3	5.45	10.49	9.75	16.43	20.24	9.75	15.83	21.12	31.15	53.17
3.1.1	TLPGCAR	TC4	1.2	2.41	2.14	3.55	4.56	2.14	2.21	2.21	2.21	2.21
3.1.1	TLPGCAR	TCX	6.82	7.57	7.61	7.61	6.78	5.36	2.89	1.72	0	0
3.1.1	TPETCAR	TC1	39.21	30.23	36.92	36.92	43.21	73.14	66.45	89.99	110.39	135.55
3.1.1	TPETCAR	TC2	55.89	43.09	52.63	52.63	57.88	77.31	82.63	96.53	100.07	105.67
3.1.1	TPETCAR	TC3	12.04	9.28	12.59	12.59	14.53	23.56	23.44	26.44	27.12	22.76
3.1.1	TPETCAR	TC4	3.1	2.39	3.22	3.22	3.72	5.95	6.7	8.17	10.56	14.39

Table A.4. Modal energy consumptions by fuel types in scenario 1.2.1 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
1.2.1	TCNGBUS	TB2	0	3.47	6.5	6.89	5.34	5.92	6.29	3.67	4.34	0
1.2.1	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
1.2.1	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.18	2.59	3.02	3.59	4.26	5.06
1.2.1	TDIE	TSDY	0.01	0.02	0.07	0.1	0.14	0.19	0.25	0.33	0.43	0.56
1.2.1	TDIE	TSKT	0.03	0.04	0.18	0.25	0.35	0.45	0.61	0.78	1	1.29
1.2.1	TDIE	TSKY	0.63	1.02	3.05	4.41	6.16	8.33	11.43	14.8	19.24	25.16
1.2.1	TDIE	TSTK	0.48	0.78	2.34	3.38	4.77	6.49	8.95	11.65	15.22	19.96
1.2.1	TDIEBUS	TB1	37.39	41.25	34.26	31.08	27.21	20.95	15.8	9.73	4.87	2.62
1.2.1	TDIEBUS	TB2	22.35	23.26	24.62	21.43	18.52	14.11	8.01	6.32	3.72	0
1.2.1	TDIEBUS	TB3	21.03	24.32	25.8	29.99	30.9	36.43	42.66	49.22	57.51	67.44
1.2.1	TDIECAR	TC1	5.36	14	15.7	15.7	16.44	10.84	12.38	14.66	13.91	9.95
1.2.1	TDIECAR	TC2	10.28	26.86	29.66	29.66	31.08	20.33	23.75	28.12	26.7	19.1
1.2.1	TDIECAR	TC3	1.47	3.84	4.3	4.3	4.51	2.97	3.39	4.02	3.81	2.73
1.2.1	TDIECAR	TC4	0.37	0.97	1.09	1.09	1.16	0.77	0.87	1.03	0.97	0.69
1.2.1	TDIECAR	TCX	0.15	0.18	0.16	0.12	0.15	0.07	0.08	0	0	0
1.2.1	TDIEHGV	TH1	153.28	140.72	112.09	107.53	104.68	103.04	41.72	31.25	20.94	10.52
1.2.1	TDIEHGV	TH2	34.91	75.89	66.27	91.1	142.21	175.94	98.61	89.95	75.07	47.64
1.2.1	TDIELGV	TL	25.58	26.16	21.04	18.21	16.03	11.8	9.88	7.79	5.46	2.67
1.2.1	TDIERAIL	TRF	4.43	4.76	13.28	14.04	14.46	14.13	12.87	10.1	11.19	13.41
1.2.1	TDIERAIL	TRM	2.37	2.38	2.08	1.91	1.66	1.44	1.21	0.91	0.81	0.82
1.2.1	TELC	TB1	0	0	0.61	2.54	4.67	7.01	9.54	12.51	14.88	16.68
1.2.1	TELC	TB2	0	0	1.02	2.92	5.98	9.1	13.19	17.55	21.64	28.14
1.2.1	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
1.2.1	TELC	TL	0	0	1.2	2.46	3.39	4.39	5.33	6.39	7.54	8.81
1.2.1	TELC	TRF	0.25	0.27	1.05	1.95	3.24	4.73	6.64	9.87	11.7	13.97
1.2.1	TELC	TRH	0	0.13	1.17	2.08	3.21	4.72	5.99	7.16	8.52	10.19
1.2.1	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
1.2.1	TELC	TRMET	0.17	0.3	0.46	0.59	0.75	0.92	1.04	1.17	1.38	1.55
1.2.1	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
1.2.1	THDGAIR	TA	0	0	0	0	0	0	0	0	0	76.01
1.2.1	THDGHGV	TH1	0	0	0	0	0	0	30.68	35.97	41	46.07
1.2.1	THDGHGV	TH2	0	0	0	0	0	0	68.52	102.02	146	206.97
1.2.1	TJETAIR	TA	15.22	22.25	65.01	82.25	90.03	121.64	136.85	182.99	205.56	205.56
1.2.1	TLPGCAR	TC1	16.57	31.14	31.14	31.14	31.14	23.74	28.09	28.09	28.09	22.16
1.2.1	TLPGCAR	TC2	24.52	46.11	51	63.39	81.06	94.46	117.18	137.71	176.7	214.13
1.2.1	TLPGCAR	TC3	5.45	10.24	11.33	14.09	18.01	20.99	26.04	30.61	39.27	47.59
1.2.1	TLPGCAR	TC4	1.2	2.41	2.41	2.41	2.41	1.72	2.03	2.03	2.03	1.6
1.2.1	TLPGCAR	TCX	6.82	7.57	8.57	8.57	7.62	5.06	2.96	1.76	0	0
1.2.1	TPETCAR	TC1	39.21	32.03	38.6	52.48	63.65	73.99	82.85	96.2	128.58	173.79
1.2.1	TPETCAR	TC2	55.89	45.65	50.36	58.32	63.16	63.41	68.56	80.52	83.68	95.29
1.2.1	TPETCAR	TC3	12.04	9.83	10.85	12.56	13.6	13.66	14.77	17.34	18.02	20.52
1.2.1	TPETCAR	TC4	3.1	2.53	3.07	4.12	5.26	6.46	7.51	9.18	11.26	14.17

Table A.5. Modal energy consumptions by fuel types in scenario 1.3.1 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
1.3.1	TCNGBUS	TB2	0	3.47	7.15	7.58	5.81	6.33	6.77	3.94	4.64	0
1.3.1	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
1.3.1	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.18	2.59	3.02	3.59	4.26	5.06
1.3.1	TDIE	TSDY	0.01	0.02	0.1	0.14	0.19	0.25	0.33	0.42	0.53	0.69
1.3.1	TDIE	TSKT	0.03	0.04	0.29	0.39	0.54	0.68	0.88	1.1	1.39	1.78
1.3.1	TDIE	TSKY	0.63	1.02	4.45	6.18	8.49	11.06	14.69	18.71	23.94	30.92
1.3.1	TDIE	TSTK	0.48	0.78	3.41	4.73	6.57	8.61	11.48	14.7	18.94	24.53
1.3.1	TDIEBUS	TB1	37.39	41.25	30.45	27.63	24.18	18.62	14.04	8.64	4.33	2.33
1.3.1	TDIEBUS	TB2	22.35	23.26	27.29	23.54	20.12	15.16	8.61	6.79	4	0
1.3.1	TDIEBUS	TB3	21.03	24.32	23.11	27	27.38	32.39	38	43.72	51.17	60.05
1.3.1	TDIECAR	TC1	5.36	14	13.96	14	14.62	9.33	11.03	13.06	12.43	8.79
1.3.1	TDIECAR	TC2	10.28	26.86	26.78	26.86	28.06	17.89	21.17	25.05	23.85	16.87
1.3.1	TDIECAR	TC3	1.47	3.84	3.83	3.84	4.05	2.6	3.06	3.62	3.41	2.41
1.3.1	TDIECAR	TC4	0.37	0.97	0.97	0.97	1.03	0.66	0.78	0.92	0.87	0.61
1.3.1	TDIECAR	TCX	0.15	0.18	0.16	0.12	0.15	0.07	0.08	0	0	0
1.3.1	TDIEHGV	TH1	153.28	140.72	99.63	95.58	93.05	92.28	36.85	27.77	18.61	9.35
1.3.1	TDIEHGV	TH2	34.91	75.89	58.91	80.98	126.41	156.39	87.66	79.96	66.73	42.35
1.3.1	TDIELGV	TL	25.58	26.16	18.7	16.18	14.25	10.49	8.78	6.92	4.85	2.37
1.3.1	TDIERAIL	TRF	4.43	4.76	21.6	23.24	24.54	24.15	22.22	17.61	19.71	23.87
1.3.1	TDIERAIL	TRM	2.37	2.38	2.08	1.91	1.66	1.44	1.21	0.91	0.81	0.82
1.3.1	TELC	TB1	0	0	0.54	2.25	4.15	6.23	8.48	11.12	13.23	10.6
1.3.1	TELC	TB2	0	0	1.13	3.2	6.5	9.78	14.17	18.86	20.31	13.84
1.3.1	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
1.3.1	TELC	TL	0	0	1.06	2.19	3.02	3.91	4.73	5.68	6.7	7.83
1.3.1	TELC	TRF	0.25	0.27	1.7	3.23	5.49	8.1	11.46	17.19	20.6	24.88
1.3.1	TELC	TRH	0	0.13	2.09	3.66	5.62	8.16	9.97	11.76	13.82	16.32
1.3.1	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
1.3.1	TELC	TRMET	0.17	0.3	0.5	0.69	0.92	1.19	1.36	1.55	1.82	2.07
1.3.1	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
1.3.1	THDGAIR	TA	0	0	0	0	0	0	0	0	0	82.94
1.3.1	THDGBUS	TB1	0	0	0	0	0	0	0	0	0	5.68
1.3.1	THDGBUS	TB2	0	0	0	0	0	0	0	0	3.96	22.01
1.3.1	THDGHGV	TH1	0	0	0	0	0	0	27.27	31.98	36.44	40.95
1.3.1	THDGHGV	TH2	0	0	0	0	0	0	60.91	90.69	129.78	183.97
1.3.1	TJETAIR	TA	15.22	22.25	97.24	114.91	118.65	149.19	165.63	217.06	240.11	240.11
1.3.1	TLPGCAR	TC1	16.57	31.14	31.05	31.14	31.14	21.1	24.97	24.97	24.97	19.7
1.3.1	TLPGCAR	TC2	24.52	46.11	45.97	56.95	72.71	83.65	104.25	122.51	157.11	190.14
1.3.1	TLPGCAR	TC3	5.45	10.24	10.21	12.65	16.16	18.59	23.17	27.23	34.92	42.26
1.3.1	TLPGCAR	TC4	1.2	2.41	2.4	2.41	2.41	1.53	1.81	1.81	1.81	1.43
1.3.1	TLPGCAR	TCX	6.82	7.57	8.57	8.57	7.62	5.06	2.96	1.76	0	0
1.3.1	TPETCAR	TC1	39.21	32.03	31.93	44.17	54.12	64.3	73.76	85.68	114.44	155.31
1.3.1	TPETCAR	TC2	55.89	45.65	45.51	52.61	56.92	56.07	61.03	71.67	74.48	84.51
1.3.1	TPETCAR	TC3	12.04	9.83	9.8	11.33	12.26	12.08	13.14	15.43	16.04	18.2
1.3.1	TPETCAR	TC4	3.1	2.53	2.52	3.44	4.46	5.67	6.68	8.17	10.01	12.58

Table A.6. Modal energy consumptions by fuel types in scenario 1.1.2 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
1.1.2	TCNGBUS	TB2	0	3.47	5.84	6.2	4.86	5.49	5.81	3.39	4.03	0
1.1.2	TCNGHGV	TH1	0	0	0	0	36.08	36.08	0	0	0	0
1.1.2	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
1.1.2	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
1.1.2	TDIE	TSDY	0.01	0.02	0.04	0.06	0.09	0.12	0.18	0.24	0.32	0.43
1.1.2	TDIE	TSKT	0.03	0.04	0.07	0.11	0.16	0.23	0.34	0.45	0.6	0.81
1.1.2	TDIE	TSKY	0.63	1.02	1.64	2.64	3.84	5.6	8.18	10.89	14.53	19.4
1.1.2	TDIE	TSTK	0.48	0.78	1.26	2.02	2.97	4.37	6.42	8.59	11.5	15.39
1.1.2	TDIEBUS	TB1	37.39	41.25	38.07	34.54	29.93	23.41	17.55	10.81	5.41	2.91
1.1.2	TDIEBUS	TB2	22.35	23.26	20.4	19.25	17.15	12.62	7.5	5.93	3.28	0
1.1.2	TDIEBUS	TB3	21.03	24.32	28.34	32.99	34.45	40.42	47.35	54.74	63.79	74.83
1.1.2	TDIECAR	TC1	5.36	14	16.57	16.57	17.28	10.32	11.93	14.14	13.42	9.66
1.1.2	TDIECAR	TC2	10.28	26.86	31.78	31.78	33.16	19.8	22.9	27.12	25.75	18.54
1.1.2	TDIECAR	TC3	1.47	3.84	4.54	4.54	4.74	2.83	3.27	3.87	3.68	2.65
1.1.2	TDIECAR	TC4	0.37	0.97	1.15	1.15	1.2	0.72	0.83	0.98	0.93	0.67
1.1.2	TDIECAR	TCX	0.15	0.18	0.16	0.12	0.15	0.07	0.08	0	0	0
1.1.2	TDIEHGV	TH1	153.28	140.72	124.54	119.48	91.9	90.07	46.35	34.72	23.26	11.69
1.1.2	TDIEHGV	TH2	34.91	75.89	65.81	102.54	159.34	196.82	104.68	99.95	83.41	52.94
1.1.2	TDIELGV	TL	25.58	26.16	23.37	20.23	16.22	13.31	11.18	8.8	5.84	2.96
1.1.2	TDIERAIL	TRF	4.43	4.76	4.96	4.83	4.39	4.1	3.52	2.59	2.67	2.94
1.1.2	TDIERAIL	TRM	2.37	2.38	2.08	1.91	1.66	1.44	1.21	0.91	0.81	0.82
1.1.2	TELC	TB1	0	0	0.68	2.82	5.19	7.79	10.6	13.9	16.53	18.54
1.1.2	TELC	TB2	0	0	0.91	2.63	5.47	8.42	12.21	16.24	20.02	26.03
1.1.2	TELC	TC1	0	0	0	0	0	0	4.29	4.29	4.29	4.29
1.1.2	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
1.1.2	TELC	TL	0	0	1.33	2.74	3.77	4.88	5.92	7.1	8.38	9.79
1.1.2	TELC	TRF	0.25	0.27	0.39	0.67	0.99	1.37	1.82	2.54	2.8	3.07
1.1.2	TELC	TRH	0	0.13	0.25	0.51	0.8	1.28	2.02	2.56	3.22	4.06
1.1.2	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
1.1.2	TELC	TRMET	0.17	0.3	0.42	0.5	0.57	0.65	0.72	0.8	0.94	1.04
1.1.2	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
1.1.2	THDGAIR	TA	0	0	0	0	0	0	0	0	128.66	273.36
1.1.2	THDGHGV	TH1	0	0	0	0	0	0	34.09	39.97	45.55	51.19
1.1.2	THDGHGV	TH2	0	0	0	0	0	0	76.13	113.36	162.23	229.96
1.1.2	TJETAIR	TA	15.22	22.25	32.24	49.06	61.42	94.04	108.06	148.91	63.31	0
1.1.2	TLPGCAR	TC1	16.57	31.14	33.28	33.73	33.73	23.11	27.11	26.66	26.66	67.15
1.1.2	TLPGCAR	TC2	24.52	46.11	54.72	66.69	83.77	91.54	113.12	132.96	170.63	207.06
1.1.2	TLPGCAR	TC3	5.45	10.24	12.16	14.82	18.61	20.34	25.14	29.55	37.92	46.01
1.1.2	TLPGCAR	TC4	1.2	2.41	2.57	2.6	2.6	1.67	1.96	1.93	1.93	1.56
1.1.2	TLPGCAR	TCX	6.82	7.57	8.57	8.57	7.62	5.06	2.96	1.76	0	0
1.1.2	TPETCAR	TC1	39.21	32.03	42.03	56.14	68.05	75.98	75.03	89.16	108.02	104.77
1.1.2	TPETCAR	TC2	55.89	45.65	53.94	61.63	66.31	61.53	66.16	77.71	80.77	92.23
1.1.2	TPETCAR	TC3	12.04	9.83	11.62	13.27	14.28	13.25	14.25	16.74	17.4	19.86
1.1.2	TPETCAR	TC4	3.1	2.53	3.35	4.41	5.63	6.19	6.81	7.89	10.19	13.8

Table A.7. Modal energy consumptions by fuel types in scenario 1.1.3 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
1.1.3	TCNGBUS	TB2	0	3.47	5.84	6.2	4.86	5.49	5.81	3.39	4.03	0
1.1.3	TCNGHGV	TH1	0	0	24.9	48.67	62.01	79.19	0	0	0	0
1.1.3	TCNGHGV	TH2	0	0	13.43	41.61	85.9	132.5	0	0	0	0
1.1.3	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
1.1.3	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
1.1.3	TDIE	TSDY	0.01	0.02	0.04	0.06	0.09	0.12	0.18	0.24	0.32	0.43
1.1.3	TDIE	TSKT	0.03	0.04	0.07	0.11	0.16	0.23	0.34	0.45	0.6	0.81
1.1.3	TDIE	TSKY	0.63	1.02	1.64	2.64	3.84	5.6	8.18	10.89	14.53	19.4
1.1.3	TDIE	TSTK	0.48	0.78	1.26	2.02	2.97	4.37	6.42	8.59	11.5	15.39
1.1.3	TDIEBUS	TB1	37.39	41.25	38.07	34.54	29.57	23.57	17.71	10.81	5.41	2.91
1.1.3	TDIEBUS	TB2	22.35	23.26	20.4	19.25	17.15	12.62	7.5	5.93	3.28	0
1.1.3	TDIEBUS	TB3	21.03	24.32	28.34	32.99	34.45	40.42	47.35	54.74	63.79	74.83
1.1.3	TDIECAR	TC1	5.36	14	16.27	16.27	16.9	9.13	10.56	12.5	11.87	8.55
1.1.3	TDIECAR	TC2	10.28	26.86	31.22	31.22	32.43	17.51	20.26	24	22.78	16.41
1.1.3	TDIECAR	TC3	1.47	3.84	4.46	4.46	4.63	2.5	2.89	3.43	3.25	2.34
1.1.3	TDIECAR	TC4	0.37	0.97	1.13	1.13	1.18	0.64	0.74	0.87	0.83	0.6
1.1.3	TDIECAR	TCX	0.15	0.18	0.16	0.12	0.15	0.07	0.08	0	0	0
1.1.3	TDIEHGV	TH1	153.28	140.72	105.7	87.48	75.36	61.38	46.65	35.01	23.26	11.69
1.1.3	TDIEHGV	TH2	34.91	75.89	57	75.17	102.6	108.78	104.68	99.95	83.41	52.94
1.1.3	TDIELGV	TL	25.58	26.16	23.37	19.47	16.32	13.42	11.24	8.8	5.84	2.96
1.1.3	TDIERAIL	TRF	4.43	4.76	4.96	4.83	4.39	4.07	3.54	2.59	2.67	2.94
1.1.3	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
1.1.3	TELC	TB1	0	0	0.68	2.82	5.19	7.79	10.6	13.9	16.53	18.54
1.1.3	TELC	TB2	0	0	0.91	2.63	5.47	8.42	12.21	16.24	20.02	26.03
1.1.3	TELC	TC1	0	0	0	0	0	0	4.29	10.74	10.74	10.74
1.1.3	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
1.1.3	TELC	TL	0	0	1.33	2.74	3.77	4.88	5.92	7.1	8.38	9.79
1.1.3	TELC	TRF	0.25	0.27	0.39	0.67	0.99	1.37	1.82	2.54	2.8	3.07
1.1.3	TELC	TRH	0	0.13	0.25	0.51	0.8	1.28	2.02	2.56	3.22	4.06
1.1.3	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
1.1.3	TELC	TRMET	0.17	0.3	0.42	0.5	0.57	0.65	0.72	0.8	0.94	1.04
1.1.3	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
1.1.3	THDGAIR	TA	0	0	0	0	0	0	0	44.8	204.27	273.36
1.1.3	THDGHGV	TH1	0	0	0	0	0	0	34.09	39.97	45.55	51.19
1.1.3	THDGHGV	TH2	0	0	0	0	0	0	76.13	113.36	162.23	229.96
1.1.3	TJETAIR	TA	15.22	22.25	32.79	49.6	61.42	93.47	108.06	108.06	0	0
1.1.3	TLPGCAR	TC1	16.57	31.14	33.03	33.44	33.44	20.44	23.98	23.58	56.29	92.11
1.1.3	TLPGCAR	TC2	24.52	46.11	53.73	64.32	79.42	80.98	100.07	117.63	150.94	183.16
1.1.3	TLPGCAR	TC3	5.45	10.24	11.94	14.29	17.65	17.99	22.24	26.14	33.55	40.7
1.1.3	TLPGCAR	TC4	1.2	2.41	2.55	2.58	2.58	1.48	1.74	1.71	1.71	1.38
1.1.3	TLPGCAR	TCX	6.82	7.57	8.57	8.57	7.62	5.06	2.96	1.76	0	0
1.1.3	TPETCAR	TC1	39.21	32.03	41.36	54.84	66.38	71	69.67	68.14	61.41	57.24
1.1.3	TPETCAR	TC2	55.89	45.65	52.99	59.79	63.93	54.43	58.53	68.75	71.45	81.58
1.1.3	TPETCAR	TC3	12.04	9.83	11.41	12.88	13.77	11.72	12.6	14.8	15.39	17.57
1.1.3	TPETCAR	TC4	3.1	2.53	3.29	4.31	5.5	5.8	6.38	7.39	9.67	13.21

Table A.8. Modal energy consumptions by fuel types in scenario 1.2.2 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
1.2.2	TCNGBUS	TB2	0	3.47	6.5	6.89	5.34	5.92	6.29	3.67	4.34	0
1.2.2	TCNGHGV	TH1	0	0	0	0	1.55	1.55	0	0	0	0
1.2.2	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
1.2.2	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
1.2.2	TDIE	TSDY	0.01	0.02	0.07	0.1	0.14	0.19	0.25	0.33	0.43	0.56
1.2.2	TDIE	TSKT	0.03	0.04	0.18	0.25	0.35	0.45	0.61	0.78	1	1.29
1.2.2	TDIE	TSKY	0.63	1.02	3.05	4.41	6.16	8.33	11.43	14.8	19.24	25.16
1.2.2	TDIE	TSTK	0.48	0.78	2.34	3.38	4.77	6.49	8.95	11.65	15.22	19.96
1.2.2	TDIEBUS	TB1	37.39	41.25	34.26	31.08	26.94	21.07	15.8	9.73	4.87	2.62
1.2.2	TDIEBUS	TB2	22.35	23.26	22.9	21.32	18.76	13.64	8.1	6.41	3.54	0
1.2.2	TDIEBUS	TB3	21.03	24.32	25.8	29.99	30.9	36.43	42.66	49.22	57.51	67.44
1.2.2	TDIECAR	TC1	5.36	14	15.27	15.27	15.91	9.21	10.76	12.75	12.1	8.65
1.2.2	TDIECAR	TC2	10.28	26.86	29.29	29.29	30.53	17.68	20.65	24.46	23.22	16.6
1.2.2	TDIECAR	TC3	1.47	3.84	4.18	4.18	4.36	2.53	2.95	3.49	3.32	2.37
1.2.2	TDIECAR	TC4	0.37	0.97	1.06	1.06	1.11	0.64	0.75	0.89	0.84	0.6
1.2.2	TDIECAR	TCX	0.15	0.18	0.16	0.12	0.15	0.07	0.08	0	0	0
1.2.2	TDIEHGV	TH1	153.28	140.72	112.09	107.53	103.21	101.56	41.72	31.25	20.94	10.52
1.2.2	TDIEHGV	TH2	34.91	75.89	59.23	92.29	143.4	177.13	94.21	89.95	75.07	47.64
1.2.2	TDIELGV	TL	25.58	26.16	21.04	18.21	14.59	11.98	10.06	7.92	5.26	2.67
1.2.2	TDIERAIL	TRF	4.43	4.76	13.28	14.04	14.46	14.13	12.87	10.1	11.19	13.41
1.2.2	TDIERAIL	TRM	2.37	2.38	2.08	1.91	1.66	1.44	1.21	0.91	0.81	0.82
1.2.2	TELC	TB1	0	0	0.61	2.54	4.67	7.01	9.54	12.51	14.88	16.68
1.2.2	TELC	TB2	0	0	1.02	2.92	5.98	9.1	13.19	17.55	21.64	24.95
1.2.2	TELC	TC1	0	0	0	0	0	0	3.74	3.74	3.74	3.74
1.2.2	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
1.2.2	TELC	TL	0	0	1.2	2.46	3.39	4.39	5.33	6.39	7.54	8.81
1.2.2	TELC	TRF	0.25	0.27	1.05	1.95	3.24	4.73	6.64	9.87	11.7	13.97
1.2.2	TELC	TRH	0	0.13	1.17	2.08	3.21	4.72	5.99	7.16	8.52	10.19
1.2.2	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
1.2.2	TELC	TRMET	0.17	0.3	0.46	0.59	0.75	0.92	1.04	1.17	1.38	1.55
1.2.2	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
1.2.2	THDGAIR	TA	0	0	0	0	0	0	0	0	167.64	321.55
1.2.2	THDGBUS	TB2	0	0	0	0	0	0	0	0	0	4.27
1.2.2	THDGHGV	TH1	0	0	0	0	0	0	30.68	35.97	41	46.07
1.2.2	THDGHGV	TH2	0	0	0	0	0	0	68.52	102.02	146	206.97
1.2.2	TJETAIR	TA	15.22	22.25	65.01	82.25	90.03	121.64	136.85	182.99	65.21	0
1.2.2	TLPGCAR	TC1	16.57	31.14	31.14	31.14	31.14	20.64	24.42	24.42	24.42	60.73
1.2.2	TLPGCAR	TC2	24.52	46.11	50.36	61.14	76.5	82.14	101.89	119.74	153.65	186.2
1.2.2	TLPGCAR	TC3	5.45	10.24	11.19	13.58	17	18.25	22.64	26.61	34.15	41.38
1.2.2	TLPGCAR	TC4	1.2	2.41	2.41	2.41	2.41	1.49	1.77	1.77	1.77	1.39
1.2.2	TLPGCAR	TCX	6.82	7.57	8.57	8.57	7.62	5.06	2.96	1.76	0	0
1.2.2	TPETCAR	TC1	39.21	32.03	38.17	51.32	62.04	68.19	68.06	80.31	97.28	94.19
1.2.2	TPETCAR	TC2	55.89	45.65	49.75	56.67	60.88	55.14	59.62	70.01	72.77	82.86
1.2.2	TPETCAR	TC3	12.04	9.83	10.71	12.2	13.11	11.88	12.84	15.08	15.67	17.84
1.2.2	TPETCAR	TC4	3.1	2.53	3.04	4.03	5.13	5.56	6.14	7.09	9.15	12.42

Table A.9. Modal energy consumptions by fuel types in scenario 1.2.3 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
1.2.3	TCNGBUS	TB2	0	3.47	6.5	6.89	5.34	5.92	6.29	3.67	4.34	0
1.2.3	TCNGHGV	TH1	0	0	22.41	43.8	55.8	71.27	0	0	0	0
1.2.3	TCNGHGV	TH2	0	0	12.09	37.45	77.31	119.25	0	0	0	0
1.2.3	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
1.2.3	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
1.2.3	TDIE	TSDY	0.01	0.02	0.07	0.1	0.14	0.19	0.25	0.33	0.43	0.56
1.2.3	TDIE	TSKT	0.03	0.04	0.18	0.25	0.35	0.45	0.61	0.78	1	1.29
1.2.3	TDIE	TSKY	0.63	1.02	3.05	4.41	6.16	8.33	11.43	14.8	19.24	25.16
1.2.3	TDIE	TSTK	0.48	0.78	2.34	3.38	4.77	6.49	8.95	11.65	15.22	19.96
1.2.3	TDIEBUS	TB1	37.39	41.25	34.26	31.08	26.62	21.22	15.94	9.73	4.87	2.62
1.2.3	TDIEBUS	TB2	22.35	23.26	22.9	21.32	18.76	13.64	8.1	6.41	3.54	0
1.2.3	TDIEBUS	TB3	21.03	24.32	25.8	29.99	30.9	36.43	42.66	49.22	57.51	67.44
1.2.3	TDIECAR	TC1	5.36	14	15.27	15.27	15.91	9.21	10.76	12.75	12.1	8.65
1.2.3	TDIECAR	TC2	10.28	26.86	29.29	29.29	30.53	17.68	20.65	24.46	23.22	16.6
1.2.3	TDIECAR	TC3	1.47	3.84	4.18	4.18	4.36	2.53	2.95	3.49	3.32	2.37
1.2.3	TDIECAR	TC4	0.37	0.97	1.06	1.06	1.11	0.64	0.75	0.89	0.84	0.6
1.2.3	TDIECAR	TCX	0.15	0.18	0.16	0.12	0.15	0.07	0.08	0	0	0
1.2.3	TDIEHGV	TH1	153.28	140.72	95.13	78.74	67.83	55.24	41.98	31.51	20.94	10.52
1.2.3	TDIEHGV	TH2	34.91	75.89	51.3	67.65	92.34	97.9	94.21	89.95	75.07	47.64
1.2.3	TDIELGV	TL	25.58	26.16	21.04	17.52	14.69	12.08	10.11	7.92	5.26	2.67
1.2.3	TDIERAIL	TRF	4.43	4.76	13.28	14.04	14.46	14.07	12.92	10.1	11.19	13.41
1.2.3	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
1.2.3	TELC	TB1	0	0	0.61	2.54	4.67	7.01	9.54	12.51	14.88	14.55
1.2.3	TELC	TB2	0	0	1.02	2.92	5.98	9.1	13.19	17.55	19.5	13.52
1.2.3	TELC	TC1	0	0	0	0	0	0	5.54	9.55	9.55	9.55
1.2.3	TELC	TC2	0	0	0	0	0	0	7.76	7.76	7.76	7.76
1.2.3	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
1.2.3	TELC	TL	0	0	1.2	2.46	3.39	4.39	5.33	6.39	7.54	8.81
1.2.3	TELC	TRF	0.25	0.27	1.05	1.95	3.24	4.73	6.64	9.87	11.7	13.97
1.2.3	TELC	TRH	0	0.13	1.17	2.08	3.21	4.72	5.99	7.16	8.52	10.19
1.2.3	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
1.2.3	TELC	TRMET	0.17	0.3	0.46	0.59	0.75	0.92	1.04	1.17	1.38	1.55
1.2.3	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
1.2.3	THDGAIR	TA	0	0	0	0	0	0	0	48.49	245.53	321.55
1.2.3	THDGBUS	TB1	0	0	0	0	0	0	0	0	0	2.87
1.2.3	THDGBUS	TB2	0	0	0	0	0	0	0	0	2.87	19.63
1.2.3	THDGHGV	TH1	0	0	0	0	0	0	30.68	35.97	41	46.07
1.2.3	THDGHGV	TH2	0	0	0	0	0	0	68.52	102.02	146	206.97
1.2.3	TJETAIR	TA	15.22	22.25	65.01	82.25	90.03	121.64	136.85	138.58	0	0
1.2.3	TLPGCAR	TC1	16.57	31.14	31.14	31.14	31.14	20.64	24.42	24.42	24.42	19.27
1.2.3	TLPGCAR	TC2	24.52	46.11	50.36	61.14	76.5	82.14	77.89	95.74	129.65	162.2
1.2.3	TLPGCAR	TC3	5.45	10.24	11.19	13.58	17	18.25	22.64	26.61	34.15	41.38
1.2.3	TLPGCAR	TC4	1.2	2.41	2.41	2.41	2.41	1.49	1.77	1.77	1.77	1.39
1.2.3	TLPGCAR	TCX	6.82	7.57	8.57	8.57	7.62	5.06	2.96	1.76	0	0
1.2.3	TPETCAR	TC1	39.21	32.03	38.17	51.32	62.04	68.19	62.05	67.05	84.03	128.18
1.2.3	TPETCAR	TC2	55.89	45.65	49.75	56.67	60.88	55.14	59.62	70.01	72.77	82.86
1.2.3	TPETCAR	TC3	12.04	9.83	10.71	12.2	13.11	11.88	12.84	15.08	15.67	17.84
1.2.3	TPETCAR	TC4	3.1	2.53	3.04	4.03	5.13	5.56	6.14	7.09	9.15	12.42

Table A.10. Modal energy consumptions by fuel types in scenario 1.3.2 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
1.3.2	TCNGBUS	TB2	0	3.47	7.15	7.58	5.81	6.33	6.77	3.94	4.64	0
1.3.2	TCNGHGV	TH1	0	0	0	0	1.76	1.76	0	0	0	0
1.3.2	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
1.3.2	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
1.3.2	TDIE	TSDY	0.01	0.02	0.1	0.14	0.19	0.25	0.33	0.42	0.53	0.69
1.3.2	TDIE	TSKT	0.03	0.04	0.29	0.39	0.54	0.68	0.88	1.1	1.39	1.78
1.3.2	TDIE	TSKY	0.63	1.02	4.45	6.18	8.49	11.06	14.69	18.71	23.94	30.92
1.3.2	TDIE	TSTK	0.48	0.78	3.41	4.73	6.57	8.61	11.48	14.7	18.94	24.53
1.3.2	TDIEBUS	TB1	37.39	41.25	30.45	27.63	23.94	18.73	14.04	8.64	4.33	2.33
1.3.2	TDIEBUS	TB2	22.35	23.26	25.41	23.39	20.38	14.66	8.71	6.89	3.81	0
1.3.2	TDIEBUS	TB3	21.03	24.32	23.11	27	27.38	32.39	38	43.72	51.17	60.05
1.3.2	TDIECAR	TC1	5.36	14	13.96	14	14.54	8.11	9.59	11.35	10.81	7.64
1.3.2	TDIECAR	TC2	10.28	26.86	26.78	26.86	27.9	15.56	18.41	21.79	20.74	14.67
1.3.2	TDIECAR	TC3	1.47	3.84	3.83	3.84	3.99	2.22	2.63	3.11	2.96	2.1
1.3.2	TDIECAR	TC4	0.37	0.97	0.97	0.97	1.01	0.56	0.67	0.79	0.75	0.53
1.3.2	TDIECAR	TCX	0.15	0.18	0.16	0.12	0.15	0.07	0.08	0	0	0
1.3.2	TDIEHGV	TH1	153.28	140.72	99.63	95.58	91.49	90.02	37.08	27.77	18.61	9.35
1.3.2	TDIEHGV	TH2	34.91	75.89	52.65	82.04	127.47	157.45	83.75	79.96	66.73	42.35
1.3.2	TDIELGV	TL	25.58	26.16	18.7	16.18	12.97	10.65	8.95	7.04	4.67	2.37
1.3.2	TDIERAIL	TRF	4.43	4.76	21.6	23.24	24.54	24.15	22.22	17.61	19.71	23.87
1.3.2	TDIERAIL	TRM	2.37	2.38	2.08	1.91	1.66	1.44	1.21	0.91	0.81	0.82
1.3.2	TELC	TB1	0	0	0.54	2.25	4.15	6.23	8.48	11.12	13.23	10.6
1.3.2	TELC	TB2	0	0	1.13	3.2	6.5	9.78	14.17	18.86	17.68	11.22
1.3.2	TELC	TC1	0	0	0	0	0	0	2.63	2.63	2.63	2.63
1.3.2	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
1.3.2	TELC	TL	0	0	1.06	2.19	3.02	3.91	4.73	5.68	6.7	7.83
1.3.2	TELC	TRF	0.25	0.27	1.7	3.23	5.49	8.1	11.46	17.19	20.6	24.88
1.3.2	TELC	TRH	0	0.13	2.09	3.66	5.62	8.16	9.97	11.76	13.82	16.32
1.3.2	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
1.3.2	TELC	TRMET	0.17	0.3	0.5	0.69	0.92	1.19	1.36	1.55	1.82	2.07
1.3.2	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
1.3.2	THDGAIR	TA	0	0	0	0	0	0	0	0	206.59	369.73
1.3.2	THDGBUS	TB1	0	0	0	0	0	0	0	0	0	5.68
1.3.2	THDGBUS	TB2	0	0	0	0	0	0	0	0	7.49	25.54
1.3.2	THDGHGV	TH1	0	0	0	0	0	0	27.27	31.98	36.44	40.95
1.3.2	THDGHGV	TH2	0	0	0	0	0	0	60.91	90.69	129.78	183.97
1.3.2	TJETAIR	TA	15.22	22.25	97.24	114.91	118.65	149.19	165.63	211.65	67.15	0
1.3.2	TLPGCAR	TC1	16.57	31.14	31.05	31.14	31.14	18.35	21.71	21.71	21.71	56.29
1.3.2	TLPGCAR	TC2	24.52	46.11	45.97	55.53	69.24	72.74	90.65	106.53	136.61	165.35
1.3.2	TLPGCAR	TC3	5.45	10.24	10.21	12.34	15.39	16.17	20.15	23.68	30.36	36.74
1.3.2	TLPGCAR	TC4	1.2	2.41	2.4	2.41	2.41	1.33	1.57	1.57	1.57	1.24
1.3.2	TLPGCAR	TCX	6.82	7.57	8.57	8.57	7.62	5.06	2.96	1.76	0	0
1.3.2	TPETCAR	TC1	39.21	32.03	31.93	43.53	53.09	59.17	62.19	73.14	88.2	83.55
1.3.2	TPETCAR	TC2	55.89	45.65	45.51	51.7	55.45	48.75	53.07	62.32	64.77	73.49
1.3.2	TPETCAR	TC3	12.04	9.83	9.8	11.14	11.94	10.5	11.43	13.42	13.95	15.83
1.3.2	TPETCAR	TC4	3.1	2.53	2.52	3.39	4.38	4.8	5.48	6.31	8.14	11.11

Table A.11. Modal energy consumptions by fuel types in scenario 1.3.3 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
1.3.3	TCNGBUS	TB2	0	3.47	7.15	7.58	5.81	6.33	6.77	3.94	4.64	0
1.3.3	TCNGHGV	TH1	0	0	19.92	38.93	49.6	63.36	0	0	0	0
1.3.3	TCNGHGV	TH2	0	0	10.74	33.29	68.72	106	0	0	0	0
1.3.3	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
1.3.3	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
1.3.3	TDIE	TSDY	0.01	0.02	0.1	0.14	0.19	0.25	0.33	0.42	0.53	0.69
1.3.3	TDIE	TSKT	0.03	0.04	0.29	0.39	0.54	0.68	0.88	1.1	1.39	1.78
1.3.3	TDIE	TSKY	0.63	1.02	4.45	6.18	8.49	11.06	14.69	18.71	23.94	30.92
1.3.3	TDIE	TSTK	0.48	0.78	3.41	4.73	6.57	8.61	11.48	14.7	18.94	24.53
1.3.3	TDIEBUS	TB1	37.39	41.25	30.45	27.63	23.66	18.86	14.17	8.64	4.33	2.33
1.3.3	TDIEBUS	TB2	22.35	23.26	25.41	23.39	20.38	14.66	8.71	6.89	3.81	0
1.3.3	TDIEBUS	TB3	21.03	24.32	23.11	27	27.38	32.39	38	43.72	51.17	60.05
1.3.3	TDIECAR	TC1	5.36	14	13.96	14	14.54	8.11	9.59	11.35	10.81	7.64
1.3.3	TDIECAR	TC2	10.28	26.86	26.78	26.86	27.9	15.56	18.41	21.79	20.74	14.67
1.3.3	TDIECAR	TC3	1.47	3.84	3.83	3.84	3.99	2.22	2.63	3.11	2.96	2.1
1.3.3	TDIECAR	TC4	0.37	0.97	0.97	0.97	1.01	0.56	0.67	0.79	0.75	0.53
1.3.3	TDIECAR	TCX	0.15	0.18	0.16	0.12	0.15	0.07	0.08	0	0	0
1.3.3	TDIEHGV	TH1	153.28	140.72	84.56	69.99	60.29	49.11	37.32	28.01	18.61	9.35
1.3.3	TDIEHGV	TH2	34.91	75.89	45.6	60.14	82.08	87.02	83.75	79.96	66.73	42.35
1.3.3	TDIELGV	TL	25.58	26.16	18.7	15.9	13.01	10.69	8.95	7.04	4.67	2.37
1.3.3	TDIERAIL	TRF	4.43	4.76	21.6	23.24	24.54	24.07	22.3	17.61	19.71	23.87
1.3.3	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
1.3.3	TELC	TB1	0	0	0.54	2.25	4.15	6.23	8.48	11.12	9.75	7.12
1.3.3	TELC	TB2	0	0	1.13	3.2	6.5	9.78	14.17	18.86	14.46	8
1.3.3	TELC	TC1	0	0	0	0	0	0	3.53	3.53	3.53	3.53
1.3.3	TELC	TC2	0	0	0	0	0	0	5.79	5.79	5.79	5.79
1.3.3	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
1.3.3	TELC	TL	0	0	1.06	2.19	3.02	3.91	4.73	5.68	6.7	7.83
1.3.3	TELC	TRF	0.25	0.27	1.7	3.23	5.49	8.1	11.46	17.19	20.6	24.88
1.3.3	TELC	TRH	0	0.13	2.09	3.66	5.62	8.16	9.97	11.76	13.82	16.32
1.3.3	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
1.3.3	TELC	TRMET	0.17	0.3	0.5	0.69	0.92	1.19	1.36	1.55	1.82	2.07
1.3.3	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
1.3.3	THDGAIR	TA	0	0	0	0	0	0	0	51.78	286.8	369.73
1.3.3	THDGBUS	TB1	0	0	0	0	0	0	0	0	4.68	10.36
1.3.3	THDGBUS	TB2	0	0	0	0	0	0	0	0	11.81	29.86
1.3.3	THDGHGV	TH1	0	0	0	0	0	0	27.27	31.98	36.44	40.95
1.3.3	THDGHGV	TH2	0	0	0	0	0	0	60.91	90.69	129.78	183.97
1.3.3	TJETAIR	TA	15.22	22.25	96.78	114.45	118.65	149.19	165.63	169.41	0	0
1.3.3	TLPGCAR	TC1	16.57	31.14	31.05	31.14	31.14	18.35	21.71	21.71	21.71	17.13
1.3.3	TLPGCAR	TC2	24.52	46.11	45.97	55.53	69.24	72.74	72.74	88.62	118.71	147.44
1.3.3	TLPGCAR	TC3	5.45	10.24	10.21	12.34	15.39	16.17	20.15	23.68	30.36	36.74
1.3.3	TLPGCAR	TC4	1.2	2.41	2.4	2.41	2.41	1.33	1.57	1.57	1.57	1.24
1.3.3	TLPGCAR	TCX	6.82	7.57	8.57	8.57	7.62	5.06	2.96	1.76	0	0
1.3.3	TPETCAR	TC1	39.21	32.03	31.93	43.53	53.09	59.17	59.17	71.06	86.12	126.08
1.3.3	TPETCAR	TC2	55.89	45.65	45.51	51.7	55.45	48.75	53.07	62.32	64.77	73.49
1.3.3	TPETCAR	TC3	12.04	9.83	9.8	11.14	11.94	10.5	11.43	13.42	13.95	15.83
1.3.3	TPETCAR	TC4	3.1	2.53	2.52	3.39	4.38	4.8	5.48	6.31	8.14	11.11

Table A.12. Modal energy consumptions by fuel types in scenario 2.1.2 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
2.1.2	TCNGBUS	TB2	0	3.47	5.4	6.36	5.03	5.19	5.94	3.49	3.78	0
2.1.2	TCNGHGV	TH1	0	0	0	0	1.34	1.34	0	0	0	0
2.1.2	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
2.1.2	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
2.1.2	TDIE	TSDY	0.01	0.02	0.04	0.06	0.09	0.12	0.18	0.24	0.32	0.43
2.1.2	TDIE	TSKT	0.03	0.04	0.07	0.11	0.16	0.23	0.34	0.45	0.6	0.81
2.1.2	TDIE	TSKY	0.63	1.02	1.64	2.64	3.84	5.6	8.18	10.89	14.53	19.4
2.1.2	TDIE	TSTK	0.48	0.78	1.26	2.02	2.97	4.37	6.42	8.59	11.5	15.39
2.1.2	TDIEBUS	TB1	37.39	41.25	38.07	34.54	29.57	23.57	17.71	10.81	5.41	2.91
2.1.2	TDIEBUS	TB2	22.35	23.26	20.26	19.25	17.15	12.62	7.5	5.93	3.28	0
2.1.2	TDIEBUS	TB3	21.03	24.32	28.34	32.99	34.45	40.42	47.35	54.74	63.79	74.83
2.1.2	TDIECAR	TC1	5.36	14	16.57	16.57	17.28	10.32	11.93	14.14	13.42	9.66
2.1.2	TDIECAR	TC2	10.28	26.86	31.78	31.78	33.16	19.8	22.9	27.12	25.75	18.54
2.1.2	TDIECAR	TC3	1.47	3.84	4.54	4.54	4.74	2.83	3.27	3.87	3.68	2.65
2.1.2	TDIECAR	TC4	0.37	0.97	1.15	1.15	1.2	0.72	0.83	0.98	0.93	0.67
2.1.2	TDIECAR	TCX	0.15	0.18	0.16	0.12	0.15	0.07	0.08	0	0	0
2.1.2	TDIEHGV	TH1	153.28	140.72	122.04	119.48	114.93	112.23	46.65	35.01	23.26	11.69
2.1.2	TDIEHGV	TH2	34.91	75.89	65.81	102.54	159.34	196.82	104.68	99.95	83.41	52.94
2.1.2	TDIELGV	TL	25.58	26.16	22.18	18.63	16.12	13.85	11.01	8.57	5.92	3.11
2.1.2	TDIERAIL	TRF	4.43	4.76	4.96	4.83	4.39	4.1	3.52	2.59	2.67	2.94
2.1.2	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
2.1.2	TELC	TB1	0	0	0.68	2.82	5.19	7.79	10.6	13.9	16.53	18.54
2.1.2	TELC	TB2	0	0	0.91	2.63	5.47	8.42	12.21	16.24	20.02	26.03
2.1.2	TELC	TC1	0	0	0	0	0	0	4.29	4.29	4.29	4.29
2.1.2	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
2.1.2	TELC	TL	0	0	1.33	2.74	3.77	4.88	5.92	7.1	8.38	9.79
2.1.2	TELC	TRF	0.25	0.27	0.39	0.67	0.99	1.37	1.82	2.54	2.8	3.07
2.1.2	TELC	TRH	0	0.13	0.25	0.51	0.8	1.28	2.02	2.56	3.22	4.06
2.1.2	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
2.1.2	TELC	TRMET	0.17	0.3	0.42	0.5	0.57	0.65	0.72	0.8	0.94	1.04
2.1.2	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
2.1.2	THDGAIR	TA	0	0	0	0	0	0	0	0	173.68	273.36
2.1.2	THDGHGV	TH1	0	0	0	0	0	0	34.09	39.97	45.55	51.19
2.1.2	THDGHGV	TH2	0	0	0	0	0	0	76.13	113.36	162.23	229.96
2.1.2	TJETAIR	TA	15.22	22.25	32.24	49.06	61.42	94.04	108.06	148.91	25.61	0
2.1.2	TLPGCAR	TC1	16.57	31.14	33.28	33.73	33.73	23.11	27.11	26.66	26.66	67.15
2.1.2	TLPGCAR	TC2	24.52	46.11	54.72	66.69	83.77	91.54	113.12	132.96	170.63	207.06
2.1.2	TLPGCAR	TC3	5.45	10.24	12.16	14.82	18.61	20.34	25.14	29.55	37.92	46.01
2.1.2	TLPGCAR	TC4	1.2	2.41	2.57	2.6	2.6	1.67	1.96	1.93	1.93	1.56
2.1.2	TLPGCAR	TCX	6.82	7.57	8.57	8.57	7.62	5.06	2.96	1.76	0	0
2.1.2	TPETCAR	TC1	39.21	30.23	40.24	54.34	66.25	75.98	75.03	89.16	108.02	104.77
2.1.2	TPETCAR	TC2	55.89	43.09	51.38	59.07	63.75	61.53	66.16	77.71	80.77	92.23
2.1.2	TPETCAR	TC3	12.04	9.28	11.07	12.72	13.73	13.25	14.25	16.74	17.4	19.86
2.1.2	TPETCAR	TC4	3.1	2.53	3.3	4.36	5.58	6.14	6.81	7.89	10.19	13.8

Table A.13. Modal energy consumptions by fuel types in scenario 2.1.3 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
2.1.3	TCNGBUS	TB2	0	3.47	5.4	6.36	5.03	5.19	5.94	3.49	3.78	0
2.1.3	TCNGHGV	TH1	0	0	24.9	48.67	62.01	79.19	0	0	0	0
2.1.3	TCNGHGV	TH2	0	0	13.43	41.61	85.9	132.5	0	0	0	0
2.1.3	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
2.1.3	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
2.1.3	TDIE	TSDY	0.01	0.02	0.04	0.06	0.09	0.12	0.18	0.24	0.32	0.43
2.1.3	TDIE	TSKT	0.03	0.04	0.07	0.11	0.16	0.23	0.34	0.45	0.6	0.81
2.1.3	TDIE	TSKY	0.63	1.02	1.64	2.64	3.84	5.6	8.18	10.89	14.53	19.4
2.1.3	TDIE	TSTK	0.48	0.78	1.26	2.02	2.97	4.37	6.42	8.59	11.5	15.39
2.1.3	TDIEBUS	TB1	37.39	41.25	38.07	34.54	29.57	23.57	17.71	10.81	5.41	2.91
2.1.3	TDIEBUS	TB2	22.35	23.26	20.26	19.25	17.15	12.62	7.5	5.93	3.28	0
2.1.3	TDIEBUS	TB3	21.03	24.32	28.34	32.99	34.45	40.42	47.35	54.74	63.79	74.83
2.1.3	TDIECAR	TC1	5.36	14	16.27	16.27	16.9	9.13	10.56	12.5	11.87	8.55
2.1.3	TDIECAR	TC2	10.28	26.86	31.22	31.22	32.43	17.51	20.26	24	22.78	16.41
2.1.3	TDIECAR	TC3	1.47	3.84	4.46	4.46	4.63	2.5	2.89	3.43	3.25	2.34
2.1.3	TDIECAR	TC4	0.37	0.97	1.13	1.13	1.18	0.64	0.74	0.87	0.83	0.6
2.1.3	TDIECAR	TCX	0.15	0.18	0.16	0.12	0.15	0.07	0.08	0	0	0
2.1.3	TDIEHGV	TH1	153.28	140.72	105.7	87.48	75.36	61.38	46.65	35.01	23.26	11.69
2.1.3	TDIEHGV	TH2	34.91	75.89	57	75.17	102.6	108.78	104.68	99.95	83.41	52.94
2.1.3	TDIELGV	TL	25.58	26.16	21.18	18.04	16.04	14.04	10.72	8.45	5.92	3.11
2.1.3	TDIERAIL	TRF	4.43	4.76	4.96	4.83	4.39	4.07	3.54	2.59	2.67	2.94
2.1.3	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
2.1.3	TELC	TB1	0	0	0.68	2.82	5.19	7.79	10.6	13.9	16.53	18.54
2.1.3	TELC	TB2	0	0	0.91	2.63	5.47	8.42	12.21	16.24	20.02	26.03
2.1.3	TELC	TC1	0	0	0	0	0	0	4.16	10.62	10.62	10.62
2.1.3	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
2.1.3	TELC	TL	0	0	1.33	2.74	3.77	4.88	5.92	7.1	8.38	9.79
2.1.3	TELC	TRF	0.25	0.27	0.39	0.67	0.99	1.37	1.82	2.54	2.8	3.07
2.1.3	TELC	TRH	0	0.13	0.25	0.51	0.8	1.28	2.02	2.56	3.22	4.06
2.1.3	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
2.1.3	TELC	TRMET	0.17	0.3	0.42	0.5	0.57	0.65	0.72	0.8	0.94	1.04
2.1.3	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
2.1.3	THDGAIR	TA	0	0	0	0	0	0	0	44.8	204.27	273.36
2.1.3	THDGHGV	TH1	0	0	0	0	0	0	34.09	39.97	45.55	51.19
2.1.3	THDGHGV	TH2	0	0	0	0	0	0	76.13	113.36	162.23	229.96
2.1.3	TJETAIR	TA	15.22	22.25	32.24	49.06	61.42	94.04	108.06	108.06	0	0
2.1.3	TLPGCAR	TC1	16.57	31.14	33.45	33.45	33.45	20.45	23.95	23.95	56.67	92.48
2.1.3	TLPGCAR	TC2	24.52	46.11	53.73	64.32	79.42	80.98	100.07	117.63	150.94	183.16
2.1.3	TLPGCAR	TC3	5.45	10.24	11.94	14.29	17.65	17.99	22.24	26.14	33.55	40.7
2.1.3	TLPGCAR	TC4	1.2	2.41	2.55	2.58	2.58	1.48	1.74	1.71	1.71	1.38
2.1.3	TLPGCAR	TCX	6.82	7.57	8.57	8.57	7.62	5.06	2.96	1.76	0	0
2.1.3	TPETCAR	TC1	39.21	30.23	39.05	53.04	64.57	70.99	70.19	68.14	61.41	57.24
2.1.3	TPETCAR	TC2	55.89	43.09	50.43	57.23	61.37	54.43	58.53	68.75	71.45	81.58
2.1.3	TPETCAR	TC3	12.04	9.28	10.86	12.33	13.22	11.72	12.6	14.8	15.39	17.57
2.1.3	TPETCAR	TC4	3.1	2.53	3.24	4.26	5.45	5.75	6.38	7.39	9.67	13.21

Table A.14. Modal energy consumptions by fuel types in scenario 3.1.2 (PJ).

Scenario	**Fuel**	**Vehicle**	**2006**	**2011**	**2016**	**2021**	**2026**	**2031**	**2036**	**2041**	**2046**	**2051**
3.1.2	TCNGBUS	TB2	0	3.47	5.4	6.36	5.03	5.19	5.94	3.49	3.78	0
3.1.2	TCNGHGV	TH1	0	0	0	0	1.34	1.34	0	0	0	0
3.1.2	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
3.1.2	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
3.1.2	TDIE	TSDY	0.01	0.02	0.04	0.06	0.09	0.12	0.18	0.24	0.32	0.43
3.1.2	TDIE	TSKT	0.03	0.04	0.07	0.11	0.16	0.23	0.34	0.45	0.6	0.81
3.1.2	TDIE	TSKY	0.63	1.02	1.64	2.64	3.84	5.6	8.18	10.89	14.53	19.4
3.1.2	TDIE	TSTK	0.48	0.78	1.26	2.02	2.97	4.37	6.42	8.59	11.5	15.39
3.1.2	TDIEBUS	TB1	37.39	41.25	38.07	34.54	29.01	23.83	17.44	10.53	5.53	2.91
3.1.2	TDIEBUS	TB2	22.35	23.26	20.26	19.25	17.15	12.62	7.5	5.93	3.28	0
3.1.2	TDIEBUS	TB3	21.03	24.32	25.42	30.84	35.36	39.82	47.07	55.22	62.88	74.12
3.1.2	TDIECAR	TC1	5.36	13.63	16.2	16.2	16.92	10.32	11.93	14.14	13.42	9.66
3.1.2	TDIECAR	TC2	10.28	26.15	31.08	31.08	32.46	19.8	22.9	27.12	25.75	18.54
3.1.2	TDIECAR	TC3	1.47	3.74	4.44	4.44	4.64	2.83	3.27	3.87	3.68	2.65
3.1.2	TDIECAR	TC4	0.37	0.97	1.15	1.15	1.2	0.72	0.83	0.98	0.93	0.67
3.1.2	TDIECAR	TCX	0.15	0.18	0.14	0.11	0.13	0.08	0.08	0	0	0
3.1.2	TDIEHGV	TH1	153.28	140.72	122.04	119.48	114.93	112.23	46.65	35.01	23.26	11.69
3.1.2	TDIEHGV	TH2	34.91	75.89	65.81	102.54	158.47	197.16	105.63	99.95	83.41	52.94
3.1.2	TDIELGV	TL	25.58	26.16	20.57	17.8	16.04	14.04	10.72	8.45	5.92	3.11
3.1.2	TDIERAIL	TRF	4.43	4.76	4.96	4.83	4.39	4.1	3.52	2.59	2.67	2.94
3.1.2	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
3.1.2	TELC	TB1	0	0	0.68	2.82	5.19	7.79	10.6	13.9	16.53	18.54
3.1.2	TELC	TB2	0	0	0.91	2.63	5.47	8.42	12.21	16.24	20.02	26.03
3.1.2	TELC	TC1	0	0	0	0	0	0	4.29	4.29	4.29	4.29
3.1.2	TELC	TC2	0	0	1.81	1.81	1.81	1.81	0	0	0	0
3.1.2	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
3.1.2	TELC	TL	0	0	1.33	2.74	3.77	4.88	5.92	7.1	8.38	9.79
3.1.2	TELC	TRF	0.25	0.27	0.39	0.67	0.99	1.37	1.82	2.54	2.8	3.07
3.1.2	TELC	TRH	0	0.13	0.25	0.51	0.8	1.28	2.02	2.56	3.22	4.06
3.1.2	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
3.1.2	TELC	TRMET	0.17	0.3	0.42	0.5	0.57	0.65	0.72	0.8	0.94	1.04
3.1.2	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
3.1.2	THDGAIR	TA	0	0	0	0	0	0	0	0	173.68	273.36
3.1.2	THDGHGV	TH1	0	0	0	0	0	0	34.09	39.97	45.55	51.19
3.1.2	THDGHGV	TH2	0	0	0	0	0	0	76.13	113.36	162.23	229.96
3.1.2	TJETAIR	TA	15.22	22.25	32.24	49.06	61.42	94.04	108.06	144.61	25.61	0
3.1.2	TLPGCAR	TC1	16.57	31.14	30.98	40.51	40.51	23.59	26.93	26.93	26.93	73.71
3.1.2	TLPGCAR	TC2	24.52	46.11	42.76	69.72	79	86.77	111.91	132.59	170.98	207.41
3.1.2	TLPGCAR	TC3	5.45	10.24	9.5	15.49	17.55	19.28	24.87	29.47	38	46.09
3.1.2	TLPGCAR	TC4	1.2	2.41	2.57	2.6	2.6	1.67	1.96	1.93	1.93	1.56
3.1.2	TLPGCAR	TCX	6.82	7.57	7.61	7.61	6.78	5.36	2.89	1.72	0	0
3.1.2	TPETCAR	TC1	39.21	30.23	40.24	46.46	58.37	72.57	71.62	89.13	107.99	100.27
3.1.2	TPETCAR	TC2	55.89	43.09	51.38	51.38	63.57	61.34	65.97	78.06	80.43	91.89
3.1.2	TPETCAR	TC3	12.04	9.28	12.33	12.33	14.95	14.47	14.21	16.81	17.32	19.79
3.1.2	TPETCAR	TC4	3.1	2.53	3.3	4.36	5.58	6.14	6.81	7.89	10.19	13.8

Table A.15. Modal energy consumptions by fuel types in scenario 3.1.3 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
3.1.3	TCNGBUS	TB2	0	3.47	5.4	6.36	5.03	5.19	5.94	3.49	3.78	0
3.1.3	TCNGHGV	TH1	0	0	0	47.29	62.48	76.97	0	0	0	0
3.1.3	TCNGHGV	TH2	0	0	0	28.18	84.45	119.74	0	0	0	0
3.1.3	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
3.1.3	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
3.1.3	TDIE	TSDY	0.01	0.02	0.04	0.06	0.09	0.12	0.18	0.24	0.32	0.43
3.1.3	TDIE	TSKT	0.03	0.04	0.07	0.11	0.16	0.23	0.34	0.45	0.6	0.81
3.1.3	TDIE	TSKY	0.63	1.02	1.64	2.64	3.84	5.6	8.18	10.89	14.53	19.4
3.1.3	TDIE	TSTK	0.48	0.78	1.26	2.02	2.97	4.37	6.42	8.59	11.5	15.39
3.1.3	TDIEBUS	TB1	37.39	41.25	38.07	34.54	29.57	23.57	17.71	10.81	5.41	2.91
3.1.3	TDIEBUS	TB2	22.35	23.26	20.26	19.25	17.15	12.62	7.5	5.93	3.28	0
3.1.3	TDIEBUS	TB3	21.03	24.32	25.42	30.84	35.36	39.82	47.07	55.22	62.88	74.12
3.1.3	TDIECAR	TC1	5.36	13.63	15.9	15.9	16.54	9.13	10.56	12.5	11.87	8.55
3.1.3	TDIECAR	TC2	10.28	26.15	30.51	30.51	31.73	17.51	20.26	24	22.78	16.41
3.1.3	TDIECAR	TC3	1.47	3.84	4.46	4.46	4.63	2.5	2.89	3.43	3.25	2.34
3.1.3	TDIECAR	TC4	0.37	0.97	1.13	1.13	1.18	0.64	0.74	0.87	0.83	0.6
3.1.3	TDIECAR	TCX	0.15	0.18	0.15	0.11	0.14	0.08	0.08	0	0	0
3.1.3	TDIEHGV	TH1	153.28	140.72	122.04	87.48	75.36	61.38	46.65	35.01	23.26	11.69
3.1.3	TDIEHGV	TH2	34.91	75.89	65.81	83.98	102.6	117.59	105.63	99.95	83.41	52.94
3.1.3	TDIELGV	TL	25.58	26.16	20.57	17.8	16.04	14.04	10.72	8.45	5.92	3.11
3.1.3	TDIERAIL	TRF	4.43	4.76	4.96	4.83	4.39	4.07	3.54	2.59	2.67	2.94
3.1.3	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
3.1.3	TELC	TB1	0	0	0.68	2.82	5.19	7.79	10.6	13.9	16.53	18.54
3.1.3	TELC	TB2	0	0	0.91	2.63	5.47	8.42	12.21	16.24	20.02	26.03
3.1.3	TELC	TC1	0	0	0	0	0	0	4.29	9.79	9.79	9.79
3.1.3	TELC	TC2	0	0	1.81	1.81	1.81	1.81	0	0	0	0
3.1.3	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
3.1.3	TELC	TL	0	0	1.33	2.74	3.77	4.88	5.92	7.1	8.38	9.79
3.1.3	TELC	TRF	0.25	0.27	0.39	0.67	0.99	1.37	1.82	2.54	2.8	3.07
3.1.3	TELC	TRH	0	0.13	0.25	0.51	0.8	1.28	2.02	2.56	3.22	4.06
3.1.3	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
3.1.3	TELC	TRMET	0.17	0.3	0.42	0.5	0.57	0.65	0.72	0.8	0.94	1.04
3.1.3	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
3.1.3	THDGAIR	TA	0	0	0	0	0	0	17.18	61.98	204.27	273.36
3.1.3	THDGHGV	TH1	0	0	0	0	0	0	34.09	39.97	45.55	51.19
3.1.3	THDGHGV	TH2	0	0	0	0	0	0	76.13	113.36	162.23	229.96
3.1.3	TJETAIR	TA	15.22	22.25	32.24	49.06	61.42	94.04	94.05	94.05	0	0
3.1.3	TLPGCAR	TC1	16.57	31.14	33.03	38.82	38.82	20.7	24.24	21.26	53.97	94.92
3.1.3	TLPGCAR	TC2	24.52	46.11	42.34	62.3	74.98	76.54	99.22	117.51	151.05	183.27
3.1.3	TLPGCAR	TC3	5.45	10.24	8.9	14.89	16.71	17.06	22	26.07	33.61	40.77
3.1.3	TLPGCAR	TC4	1.2	2.41	2.55	2.58	2.58	1.48	1.74	1.71	1.71	1.38
3.1.3	TLPGCAR	TCX	6.82	7.57	7.61	7.61	6.78	5.36	2.89	1.72	0	0
3.1.3	TPETCAR	TC1	39.21	30.23	39.57	46.11	57.64	68.18	66.85	72.26	65.53	57.24
3.1.3	TPETCAR	TC2	55.89	43.09	50.43	54.84	61.31	54.38	58.47	68.86	71.35	81.48
3.1.3	TPETCAR	TC3	12.04	9.28	12.12	12.12	14.44	12.95	12.57	14.87	15.32	17.51
3.1.3	TPETCAR	TC4	3.1	2.53	3.24	4.26	5.45	5.75	6.38	7.39	9.67	13.21

Table A.16. Modal energy consumptions by fuel types in scenario 2.2.1 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
2.2.1	TCNGBUS	TB2	0	3.47	6.06	7.05	5.16	5.76	6.58	3.77	4.08	0
2.2.1	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
2.2.1	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
2.2.1	TDIE	TSDY	0.01	0.02	0.07	0.1	0.14	0.19	0.25	0.33	0.43	0.56
2.2.1	TDIE	TSKT	0.03	0.04	0.18	0.25	0.35	0.45	0.61	0.78	1	1.29
2.2.1	TDIE	TSKY	0.63	1.02	3.05	4.41	6.16	8.33	11.43	14.8	19.24	25.16
2.2.1	TDIE	TSTK	0.48	0.78	2.34	3.38	4.77	6.49	8.95	11.65	15.22	19.96
2.2.1	TDIEBUS	TB1	37.39	41.25	34.26	31.08	26.49	21.27	15.88	9.66	4.98	2.62
2.2.1	TDIEBUS	TB2	22.35	23.26	22.71	21.32	18.76	13.64	8.1	6.41	3.54	0
2.2.1	TDIEBUS	TB3	21.03	24.32	25.8	29.99	30.9	36.43	42.66	49.22	57.51	67.44
2.2.1	TDIECAR	TC1	5.36	14	15.46	15.46	16.2	10.59	12.38	14.66	13.91	9.95
2.2.1	TDIECAR	TC2	10.28	26.86	29.66	29.66	31.08	20.33	23.75	28.12	26.7	19.1
2.2.1	TDIECAR	TC3	1.47	3.84	4.24	4.24	4.44	2.9	3.39	4.02	3.81	2.73
2.2.1	TDIECAR	TC4	0.37	0.97	1.09	1.09	1.15	0.75	0.86	1.02	0.97	0.69
2.2.1	TDIECAR	TCX	0.15	0.18	0.16	0.12	0.15	0.07	0.08	0	0	0
2.2.1	TDIEHGV	TH1	153.28	140.72	109.84	107.53	104.24	101.29	41.98	31.51	20.94	10.52
2.2.1	TDIEHGV	TH2	34.91	75.89	59.23	92.29	142.62	177.44	95.07	89.95	75.07	47.64
2.2.1	TDIELGV	TL	25.58	26.16	21.04	17.52	14.18	12.14	10.18	7.98	5.08	2.67
2.2.1	TDIERAIL	TRF	4.43	4.76	13.28	14.04	14.46	14.07	12.92	10.1	11.19	13.41
2.2.1	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
2.2.1	TELC	TB1	0	0	0.61	2.54	4.67	7.01	9.54	12.51	14.88	16.42
2.2.1	TELC	TB2	0	0	1.02	2.92	5.98	9.1	13.19	17.55	21.64	15.65
2.2.1	TELC	TC1	0	0	0	1.75	1.75	1.75	7.3	5.54	5.54	5.54
2.2.1	TELC	TC2	0	0	0	3.52	3.52	3.52	11.28	7.76	7.76	7.76
2.2.1	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
2.2.1	TELC	TL	0	0	1.2	2.46	3.39	4.39	5.33	6.39	7.54	8.81
2.2.1	TELC	TRF	0.25	0.27	1.05	1.95	3.24	4.73	6.64	9.87	11.7	13.97
2.2.1	TELC	TRH	0	0.13	1.17	2.08	3.21	4.72	5.99	7.16	8.52	10.19
2.2.1	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
2.2.1	TELC	TRMET	0.17	0.3	0.46	0.59	0.75	0.92	1.04	1.17	1.38	1.55
2.2.1	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
2.2.1	THDGAIR	TA	0	0	0	0	0	0	0	0	0	76.01
2.2.1	THDGBUS	TB1	0	0	0	0	0	0	0	0	0	0.36
2.2.1	THDGBUS	TB2	0	0	0	0	0	0	0	0	0	16.76
2.2.1	THDGHGV	TH1	0	0	0	0	0	0	30.68	35.97	41	46.07
2.2.1	THDGHGV	TH2	0	0	0	0	0	0	68.52	102.02	146	206.97
2.2.1	TJETAIR	TA	15.22	22.25	64.51	80.03	90.03	121.64	136.85	182.99	205.56	205.56
2.2.1	TLPGCAR	TC1	16.57	31.14	31.14	31.14	31.14	23.74	28.09	28.09	28.09	22.16
2.2.1	TLPGCAR	TC2	24.52	46.11	51	51	68.67	47.04	42.15	75.08	114.07	186.53
2.2.1	TLPGCAR	TC3	5.45	10.24	11.33	14.09	18.01	10.96	16.01	20.57	29.24	47.59
2.2.1	TLPGCAR	TC4	1.2	2.41	2.41	2.41	2.41	1.72	2.03	2.03	2.03	1.6
2.2.1	TLPGCAR	TCX	6.82	7.57	8.57	8.57	7.62	5.06	2.96	1.76	0	0
2.2.1	TPETCAR	TC1	39.21	30.23	36.81	43.6	54.76	66.9	60.33	83.56	100.82	146.03
2.2.1	TPETCAR	TC2	55.89	43.09	47.8	55.76	60.6	86.69	91.84	103.8	106.97	95.29
2.2.1	TPETCAR	TC3	12.04	9.28	10.3	12.01	13.05	19.32	20.42	23	23.68	20.52
2.2.1	TPETCAR	TC4	3.1	2.39	2.89	3.94	4.78	5.68	6.35	7.37	9.76	13.11

Table A.17. Modal energy consumptions by fuel types in scenario 2.3.1 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
2.3.1	TCNGBUS	TB2	0	3.47	6.71	7.74	5.61	6.19	7.07	4.06	4.39	0
2.3.1	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
2.3.1	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
2.3.1	TDIE	TSDY	0.01	0.02	0.1	0.14	0.19	0.25	0.33	0.42	0.53	0.69
2.3.1	TDIE	TSKT	0.03	0.04	0.29	0.39	0.54	0.68	0.88	1.1	1.39	1.78
2.3.1	TDIE	TSKY	0.63	1.02	4.45	6.18	8.49	11.06	14.69	18.71	23.94	30.92
2.3.1	TDIE	TSTK	0.48	0.78	3.41	4.73	6.57	8.61	11.48	14.7	18.94	24.53
2.3.1	TDIEBUS	TB1	37.39	41.25	30.45	27.63	23.66	18.86	14.17	8.64	4.33	2.33
2.3.1	TDIEBUS	TB2	22.35	23.26	25.16	23.39	20.38	14.66	8.71	6.89	3.81	0
2.3.1	TDIEBUS	TB3	21.03	24.32	23.11	27	27.38	32.39	38	43.72	51.17	60.05
2.3.1	TDIECAR	TC1	5.36	14	13.96	14	14.62	9.33	11.03	13.06	12.43	8.79
2.3.1	TDIECAR	TC2	10.28	26.86	26.78	26.86	28.06	17.89	21.17	25.05	23.85	16.87
2.3.1	TDIECAR	TC3	1.47	3.84	3.83	3.84	4.01	2.56	3.02	3.58	3.41	2.41
2.3.1	TDIECAR	TC4	0.37	0.97	0.97	0.97	1.02	0.65	0.77	0.91	0.87	0.61
2.3.1	TDIECAR	TCX	0.15	0.18	0.16	0.12	0.15	0.07	0.08	0	0	0
2.3.1	TDIEHGV	TH1	153.28	140.72	97.63	95.58	92.65	91.19	37.08	27.77	18.61	9.35
2.3.1	TDIEHGV	TH2	34.91	75.89	52.65	82.04	126.78	157.73	84.51	79.96	66.73	42.35
2.3.1	TDIELGV	TL	25.58	26.16	18.7	14.91	12.7	10.89	9.14	6.91	4.69	2.44
2.3.1	TDIERAIL	TRF	4.43	4.76	21.6	23.24	24.54	24.15	22.22	17.61	19.71	23.87
2.3.1	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
2.3.1	TELC	TB1	0	0	0.54	2.25	4.15	6.23	8.48	11.12	9.75	7.12
2.3.1	TELC	TB2	0	0	1.13	3.2	6.5	9.78	14.17	18.86	14.46	8
2.3.1	TELC	TC1	0	0	0	0	0	0	3.53	3.53	3.53	3.53
2.3.1	TELC	TC2	0	0	0	3.08	3.08	3.08	8.87	5.79	5.79	5.79
2.3.1	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
2.3.1	TELC	TL	0	0	1.06	2.19	3.02	3.91	4.73	5.68	6.7	7.83
2.3.1	TELC	TRF	0.25	0.27	1.7	3.23	5.49	8.1	11.46	17.19	20.6	24.88
2.3.1	TELC	TRH	0	0.13	2.09	3.66	5.62	8.16	9.97	11.76	13.82	16.32
2.3.1	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
2.3.1	TELC	TRMET	0.17	0.3	0.5	0.69	0.92	1.19	1.36	1.55	1.82	2.07
2.3.1	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
2.3.1	THDGAIR	TA	0	0	0	0	0	0	0	0	36.1	119.04
2.3.1	THDGBUS	TB1	0	0	0	0	0	0	0	0	4.68	10.36
2.3.1	THDGBUS	TB2	0	0	0	0	0	0	0	0	11.81	29.86
2.3.1	THDGHGV	TH1	0	0	0	0	0	0	27.27	31.98	36.44	40.95
2.3.1	THDGHGV	TH2	0	0	0	0	0	0	60.91	90.69	129.78	183.97
2.3.1	TJETAIR	TA	15.22	22.25	96.78	112.68	118.65	149.19	165.63	211.65	209.88	209.88
2.3.1	TLPGCAR	TC1	16.57	31.14	31.05	31.14	31.14	21.1	24.97	24.97	24.97	19.7
2.3.1	TLPGCAR	TC2	24.52	46.11	45.97	46.11	61.88	72.82	72.82	101.92	136.52	169.55
2.3.1	TLPGCAR	TC3	5.45	10.24	10.21	12.65	16.16	18.59	23.17	27.23	34.92	42.26
2.3.1	TLPGCAR	TC4	1.2	2.41	2.4	2.41	2.41	1.53	1.81	1.81	1.81	1.43
2.3.1	TLPGCAR	TCX	6.82	7.57	8.57	8.57	7.62	5.06	2.96	1.76	0	0
2.3.1	TPETCAR	TC1	39.21	30.24	30.14	40.21	50.16	62.13	62.13	77.62	92.94	133.81
2.3.1	TPETCAR	TC2	55.89	43.1	42.96	50.06	54.36	56.07	61.03	71.67	74.48	84.51
2.3.1	TPETCAR	TC3	12.04	9.28	9.25	10.78	11.71	12.08	13.14	15.43	16.04	18.2
2.3.1	TPETCAR	TC4	3.1	2.39	2.38	3.3	4.32	5.2	5.92	6.83	8.68	11.72

Table A.18. Modal energy consumptions by fuel types in scenario 3.2.1 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
3.2.1	TCNGBUS	TB2	0	3.47	6.06	7.05	5.5	5.6	6.42	3.77	4.08	0
3.2.1	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
3.2.1	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
3.2.1	TDIE	TSDY	0.01	0.02	0.07	0.1	0.14	0.19	0.25	0.33	0.43	0.56
3.2.1	TDIE	TSKT	0.03	0.04	0.18	0.25	0.35	0.45	0.61	0.78	1	1.29
3.2.1	TDIE	TSKY	0.63	1.02	3.05	4.41	6.16	8.33	11.43	14.8	19.24	25.16
3.2.1	TDIE	TSTK	0.48	0.78	2.34	3.38	4.77	6.49	8.95	11.65	15.22	19.96
3.2.1	TDIEBUS	TB1	37.39	41.25	34.26	31.08	26.62	21.22	15.94	9.73	4.87	2.62
3.2.1	TDIEBUS	TB2	22.35	23.26	22.71	21.32	18.76	13.64	8.1	6.41	3.54	0
3.2.1	TDIEBUS	TB3	21.03	24.32	22.87	27.75	31.82	35.84	42.37	49.7	56.59	66.71
3.2.1	TDIECAR	TC1	5.36	13.88	13.98	12.31	18.22	11.14	12.18	14.46	14.46	12.85
3.2.1	TDIECAR	TC2	10.28	26.86	25.8	22.99	33.93	25.8	23.3	27.67	27.67	27.67
3.2.1	TDIECAR	TC3	1.47	3.74	4.14	3.68	4.34	2.9	3.39	4.02	3.81	2.73
3.2.1	TDIECAR	TC4	0.37	0.95	1.05	1.05	1.1	0.74	0.86	1.02	0.97	0.69
3.2.1	TDIECAR	TCX	0.15	0.18	0.14	0.11	0.13	0.08	0.08	0	0	0
3.2.1	TDIEHGV	TH1	153.28	140.72	109.84	107.53	104.24	98.82	42.52	32.05	20.72	10.04
3.2.1	TDIEHGV	TH2	34.91	75.89	59.23	92.29	143.4	177.13	95.07	89.95	75.07	47.64
3.2.1	TDIELGV	TL	25.58	26.16	18.51	16.02	14.43	12.64	9.64	7.6	5.33	2.8
3.2.1	TDIERAIL	TRF	4.43	4.76	13.28	14.04	14.46	14.07	12.92	10.1	11.19	13.41
3.2.1	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
3.2.1	TELC	TB1	0	0	0.61	2.54	4.67	7.01	9.54	12.51	10.78	10.44
3.2.1	TELC	TB2	0	0	1.02	2.92	5.98	9.1	13.19	10.12	5.99	0
3.2.1	TELC	TC1	0	0	1.02	1.02	1.02	1.02	5.93	6.3	6.3	6.3
3.2.1	TELC	TC2	0	0	1.63	1.63	1.63	1.63	18.96	24.97	24.97	24.97
3.2.1	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
3.2.1	TELC	TL	0	0	1.2	2.46	3.39	4.39	5.33	6.39	7.54	8.81
3.2.1	TELC	TRF	0.25	0.27	1.05	1.95	3.24	4.73	6.64	9.87	11.7	13.97
3.2.1	TELC	TRH	0	0.13	1.17	2.08	3.21	4.72	5.99	7.16	8.52	10.19
3.2.1	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
3.2.1	TELC	TRMET	0.17	0.3	0.46	0.59	0.75	0.92	1.04	1.17	1.38	1.55
3.2.1	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
3.2.1	THDGAIR	TA	0	0	0	0	0	0	0	0	88.7	164.72
3.2.1	THDGBUS	TB1	0	0	0	0	0	0	0	0	5.51	8.39
3.2.1	THDGBUS	TB2	0	0	0	0	0	0	0	10.2	21.23	38
3.2.1	THDGHGV	TH1	0	0	0	0	0	0	30.68	35.97	41	46.07
3.2.1	THDGHGV	TH2	0	0	0	0	0	0	68.52	102.02	146	206.97
3.2.1	TJETAIR	TA	15.22	22.25	64.51	80.03	90.03	117.92	136.85	178.13	131.3	131.3
3.2.1	TLPGCAR	TC1	16.57	32.04	26.67	44.96	58.7	26.67	27.52	27.52	27.52	27.52
3.2.1	TLPGCAR	TC2	24.52	47.43	39.47	66.56	86.9	81.2	41.73	41.73	81.22	119.85
3.2.1	TLPGCAR	TC3	5.45	10.54	8.77	14.79	19.31	8.77	14.25	19	28.03	47.85
3.2.1	TLPGCAR	TC4	1.2	2.41	1.93	3.2	4.34	1.93	1.99	1.99	1.99	1.99
3.2.1	TLPGCAR	TCX	6.82	7.57	7.61	7.61	6.78	5.36	2.89	1.72	0	0
3.2.1	TPETCAR	TC1	39.21	30.23	33.54	33.54	33.54	63.48	60.18	73.18	99.63	145.37
3.2.1	TPETCAR	TC2	55.89	43.09	47.8	47.8	47.8	66.93	72.08	84.59	88.21	94.94
3.2.1	TPETCAR	TC3	12.04	9.28	11.43	11.43	12.37	21.12	21.1	23.79	24.48	20.45
3.2.1	TPETCAR	TC4	3.1	2.53	3.07	3.07	3.31	5.34	6.03	7.35	9.52	12.95

Table A.19. Modal energy consumptions by fuel types in scenario 3.3.1 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
3.3.1	TCNGBUS	TB2	0	3.47	6.71	7.74	5.98	6.02	6.91	4.06	4.39	0
3.3.1	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
3.3.1	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
3.3.1	TDIE	TSDY	0.01	0.02	0.1	0.14	0.19	0.25	0.33	0.42	0.53	0.69
3.3.1	TDIE	TSKT	0.03	0.04	0.29	0.39	0.54	0.68	0.88	1.1	1.39	1.78
3.3.1	TDIE	TSKY	0.63	1.02	4.45	6.18	8.49	11.06	14.69	18.71	23.94	30.92
3.3.1	TDIE	TSTK	0.48	0.78	3.41	4.73	6.57	8.61	11.48	14.7	18.94	24.53
3.3.1	TDIEBUS	TB1	37.39	41.25	30.45	27.63	23.66	18.86	14.17	8.64	4.33	2.33
3.3.1	TDIEBUS	TB2	22.35	23.26	25.16	23.39	20.38	14.66	8.71	6.89	3.81	0
3.3.1	TDIEBUS	TB3	21.03	24.32	20.33	24.67	28.28	31.86	37.66	44.17	50.31	59.3
3.3.1	TDIECAR	TC1	5.36	14	11.95	11.95	12.76	11.95	10.79	12.82	12.82	12.82
3.3.1	TDIECAR	TC2	10.28	26.86	22.94	20.43	24.49	22.94	20.71	24.6	24.6	24.6
3.3.1	TDIECAR	TC3	1.47	3.77	3.58	3.17	4.85	2.63	3	3.55	3.55	2.46
3.3.1	TDIECAR	TC4	0.37	0.95	0.94	1	1	0.65	0.77	0.91	0.91	0.61
3.3.1	TDIECAR	TCX	0.15	0.18	0.14	0.11	0.13	0.08	0.08	0	0	0
3.3.1	TDIEHGV	TH1	153.28	140.72	97.63	95.58	92.65	87.84	37.79	28.49	18.42	8.92
3.3.1	TDIEHGV	TH2	34.91	75.89	52.65	82.04	127.47	157.45	84.51	79.96	66.73	42.35
3.3.1	TDIELGV	TL	25.58	26.16	16.45	14.24	12.83	11.24	8.57	6.76	4.73	2.49
3.3.1	TDIERAIL	TRF	4.43	4.76	21.6	23.24	24.54	24.07	22.3	17.61	19.71	23.87
3.3.1	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
3.3.1	TELC	TB1	0	0	0.54	2.25	4.15	6.23	8.48	6.58	3.97	1.35
3.3.1	TELC	TB2	0	0	1.13	3.2	6.5	9.78	14.17	10.87	6.46	0
3.3.1	TELC	TC1	0	0	0	0	0	0	5.1	8.48	8.48	8.48
3.3.1	TELC	TC2	0	0	1.45	1.45	1.45	1.45	16.85	22.2	22.2	22.2
3.3.1	TELC	TC3	0	0	0	0	0	0	0.89	0.89	0.89	0.89
3.3.1	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
3.3.1	TELC	TL	0	0	1.06	2.19	3.02	3.91	4.73	5.68	6.7	7.83
3.3.1	TELC	TRF	0.25	0.27	1.7	3.23	5.49	8.1	11.46	17.19	20.6	24.88
3.3.1	TELC	TRH	0	0.13	2.09	3.66	5.62	8.16	9.97	11.76	13.82	16.32
3.3.1	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
3.3.1	TELC	TRMET	0.17	0.3	0.5	0.69	0.92	1.19	1.36	1.55	1.82	2.07
3.3.1	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
3.3.1	THDGAIR	TA	0	0	0	0	0	0	0	0	111.73	194.67
3.3.1	THDGBUS	TB1	0	0	0	0	0	0	0	6.23	12.56	18.24
3.3.1	THDGBUS	TB2	0	0	0	0	0	0	0	10.97	22.78	40.83
3.3.1	THDGHGV	TH1	0	0	0	0	0	0	27.27	31.98	36.44	40.95
3.3.1	THDGHGV	TH2	0	0	0	0	0	0	60.91	90.69	129.78	183.97
3.3.1	TJETAIR	TA	15.22	22.25	96.78	112.68	118.65	145.6	165.63	211.65	146.56	146.56
3.3.1	TLPGCAR	TC1	16.57	32.3	23.7	38.18	55.72	23.7	24.46	24.46	24.46	24.46
3.3.1	TLPGCAR	TC2	24.52	47.65	35.08	59.02	82.31	72.18	37.09	37.09	72.19	106.53
3.3.1	TLPGCAR	TC3	5.45	10.59	7.8	13.12	16.78	7.8	8.92	13.15	20.95	38.79
3.3.1	TLPGCAR	TC4	1.2	2.41	1.72	2.77	4.11	1.72	1.77	1.77	1.77	1.77
3.3.1	TLPGCAR	TCX	6.82	7.57	7.61	7.61	6.78	5.36	2.89	1.72	0	0
3.3.1	TPETCAR	TC1	39.21	30.24	33.5	33.6	33.6	59.57	56.21	60.81	82.07	119.19
3.3.1	TPETCAR	TC2	55.89	43.1	42.96	43.1	43.1	59.2	64.16	75.29	78.5	84.21
3.3.1	TPETCAR	TC3	12.04	9.28	10.26	10.29	10.29	18.69	18.75	21.15	21.84	18.14
3.3.1	TPETCAR	TC4	3.1	2.53	2.77	2.78	2.78	4.72	5.36	6.54	8.44	11.5

Table A.20. Modal energy consumptions by fuel types in scenario 2.2.2 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
2.2.2	TCNGBUS	TB2	0	3.47	6.06	7.05	5.5	5.6	6.42	3.77	4.08	0
2.2.2	TCNGHGV	TH1	0	0	0	0	1.55	1.55	0	0	0	0
2.2.2	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
2.2.2	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
2.2.2	TDIE	TSDY	0.01	0.02	0.07	0.1	0.14	0.19	0.25	0.33	0.43	0.56
2.2.2	TDIE	TSKT	0.03	0.04	0.18	0.25	0.35	0.45	0.61	0.78	1	1.29
2.2.2	TDIE	TSKY	0.63	1.02	3.05	4.41	6.16	8.33	11.43	14.8	19.24	25.16
2.2.2	TDIE	TSTK	0.48	0.78	2.34	3.38	4.77	6.49	8.95	11.65	15.22	19.96
2.2.2	TDIEBUS	TB1	37.39	41.25	34.26	31.08	26.62	21.22	15.94	9.73	4.87	2.62
2.2.2	TDIEBUS	TB2	22.35	23.26	22.71	21.32	18.76	13.64	8.1	6.41	3.54	0
2.2.2	TDIEBUS	TB3	21.03	24.32	25.8	29.99	30.9	36.43	42.66	49.22	57.51	67.44
2.2.2	TDIECAR	TC1	5.36	14	15.27	15.27	15.91	9.21	10.76	12.75	12.1	8.65
2.2.2	TDIECAR	TC2	10.28	26.86	29.29	29.29	30.53	17.68	20.65	24.46	23.22	16.6
2.2.2	TDIECAR	TC3	1.47	3.84	4.18	4.18	4.36	2.53	2.95	3.49	3.32	2.37
2.2.2	TDIECAR	TC4	0.37	0.97	1.06	1.06	1.11	0.64	0.75	0.89	0.84	0.6
2.2.2	TDIECAR	TCX	0.15	0.18	0.16	0.12	0.15	0.07	0.08	0	0	0
2.2.2	TDIEHGV	TH1	153.28	140.72	109.84	107.53	103.21	101.56	41.72	31.25	20.94	10.52
2.2.2	TDIEHGV	TH2	34.91	75.89	59.23	92.29	143.4	177.13	94.21	89.95	75.07	47.64
2.2.2	TDIELGV	TL	25.58	26.16	19.96	16.77	14.5	12.47	9.91	7.72	5.33	2.8
2.2.2	TDIERAIL	TRF	4.43	4.76	13.28	14.04	14.46	14.13	12.87	10.1	11.19	13.41
2.2.2	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
2.2.2	TELC	TB1	0	0	0.61	2.54	4.67	7.01	9.54	12.51	14.88	16.68
2.2.2	TELC	TB2	0	0	1.02	2.92	5.98	9.1	13.19	17.55	21.64	24.95
2.2.2	TELC	TC1	0	0	0	0	0	0	3.74	3.74	3.74	3.74
2.2.2	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
2.2.2	TELC	TL	0	0	1.2	2.46	3.39	4.39	5.33	6.39	7.54	8.81
2.2.2	TELC	TRF	0.25	0.27	1.05	1.95	3.24	4.73	6.64	9.87	11.7	13.97
2.2.2	TELC	TRH	0	0.13	1.17	2.08	3.21	4.72	5.99	7.16	8.52	10.19
2.2.2	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
2.2.2	TELC	TRMET	0.17	0.3	0.46	0.59	0.75	0.92	1.04	1.17	1.38	1.55
2.2.2	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
2.2.2	THDGAIR	TA	0	0	0	0	0	0	0	0	206.81	321.55
2.2.2	THDGBUS	TB2	0	0	0	0	0	0	0	0	0	4.27
2.2.2	THDGHGV	TH1	0	0	0	0	0	0	30.68	35.97	41	46.07
2.2.2	THDGHGV	TH2	0	0	0	0	0	0	68.52	102.02	146	206.97
2.2.2	TJETAIR	TA	15.22	22.25	64.51	81.75	90.03	121.64	136.85	178.13	32.42	0
2.2.2	TLPGCAR	TC1	16.57	31.14	31.14	31.14	31.14	20.64	24.42	24.42	24.42	60.73
2.2.2	TLPGCAR	TC2	24.52	46.11	50.36	61.14	76.5	82.14	101.89	119.74	153.65	186.2
2.2.2	TLPGCAR	TC3	5.45	10.24	11.19	13.58	17	18.25	22.64	26.61	34.15	41.38
2.2.2	TLPGCAR	TC4	1.2	2.41	2.41	2.41	2.41	1.49	1.77	1.77	1.77	1.39
2.2.2	TLPGCAR	TCX	6.82	7.57	8.57	8.57	7.62	5.06	2.96	1.76	0	0
2.2.2	TPETCAR	TC1	39.21	30.23	36.38	47.05	57.77	65.71	65.58	80.31	97.28	94.19
2.2.2	TPETCAR	TC2	55.89	43.09	47.19	54.1	58.32	55.14	59.62	70.01	72.77	82.86
2.2.2	TPETCAR	TC3	12.04	9.28	10.16	11.65	12.56	11.88	12.84	15.08	15.67	17.84
2.2.2	TPETCAR	TC4	3.1	2.53	3	3.99	5.08	5.51	6.14	7.09	9.15	12.42

Table A.21. Modal energy consumptions by fuel types in scenario 2.2.3 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
2.2.3	TCNGBUS	TB2	0	3.47	6.06	7.05	5.5	5.6	6.42	3.77	4.08	0
2.2.3	TCNGHGV	TH1	0	0	22.41	43.8	55.8	71.27	0	0	0	0
2.2.3	TCNGHGV	TH2	0	0	12.09	37.45	77.31	119.25	0	0	0	0
2.2.3	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
2.2.3	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
2.2.3	TDIE	TSDY	0.01	0.02	0.07	0.1	0.14	0.19	0.25	0.33	0.43	0.56
2.2.3	TDIE	TSKT	0.03	0.04	0.18	0.25	0.35	0.45	0.61	0.78	1	1.29
2.2.3	TDIE	TSKY	0.63	1.02	3.05	4.41	6.16	8.33	11.43	14.8	19.24	25.16
2.2.3	TDIE	TSTK	0.48	0.78	2.34	3.38	4.77	6.49	8.95	11.65	15.22	19.96
2.2.3	TDIEBUS	TB1	37.39	41.25	34.26	31.08	26.62	21.22	15.94	9.73	4.87	2.62
2.2.3	TDIEBUS	TB2	22.35	23.26	22.71	21.32	18.76	13.64	8.1	6.41	3.54	0
2.2.3	TDIEBUS	TB3	21.03	24.32	25.8	29.99	30.9	36.43	42.66	49.22	57.51	67.44
2.2.3	TDIECAR	TC1	5.36	14	15.27	15.27	15.91	9.21	10.76	12.75	12.1	8.65
2.2.3	TDIECAR	TC2	10.28	26.86	29.29	29.29	30.53	17.68	20.65	24.46	23.22	16.6
2.2.3	TDIECAR	TC3	1.47	3.84	4.18	4.18	4.36	2.53	2.95	3.49	3.32	2.37
2.2.3	TDIECAR	TC4	0.37	0.97	1.06	1.06	1.11	0.64	0.75	0.89	0.84	0.6
2.2.3	TDIECAR	TCX	0.15	0.18	0.16	0.12	0.15	0.07	0.08	0	0	0
2.2.3	TDIEHGV	TH1	153.28	140.72	95.13	78.74	67.83	55.24	41.98	31.51	20.94	10.52
2.2.3	TDIEHGV	TH2	34.91	75.89	51.3	67.65	92.34	97.9	94.21	89.95	75.07	47.64
2.2.3	TDIELGV	TL	25.58	26.16	19.37	16.18	14.38	12.59	9.8	7.6	5.33	2.8
2.2.3	TDIERAIL	TRF	4.43	4.76	13.28	14.04	14.46	14.07	12.92	10.1	11.19	13.41
2.2.3	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
2.2.3	TELC	TB1	0	0	0.61	2.54	4.67	7.01	9.54	12.51	14.88	14.55
2.2.3	TELC	TB2	0	0	1.02	2.92	5.98	9.1	13.19	17.55	19.5	13.52
2.2.3	TELC	TC1	0	0	0	0	0	0	5.54	9.55	9.55	9.55
2.2.3	TELC	TC2	0	0	0	0	0	0	7.76	7.76	7.76	7.76
2.2.3	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
2.2.3	TELC	TL	0	0	1.2	2.46	3.39	4.39	5.33	6.39	7.54	8.81
2.2.3	TELC	TRF	0.25	0.27	1.05	1.95	3.24	4.73	6.64	9.87	11.7	13.97
2.2.3	TELC	TRH	0	0.13	1.17	2.08	3.21	4.72	5.99	7.16	8.52	10.19
2.2.3	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
2.2.3	TELC	TRMET	0.17	0.3	0.46	0.59	0.75	0.92	1.04	1.17	1.38	1.55
2.2.3	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
2.2.3	THDGAIR	TA	0	0	0	0	0	0	0	48.49	245.53	321.55
2.2.3	THDGBUS	TB1	0	0	0	0	0	0	0	0	0	2.87
2.2.3	THDGBUS	TB2	0	0	0	0	0	0	0	0	2.87	19.63
2.2.3	THDGHGV	TH1	0	0	0	0	0	0	30.68	35.97	41	46.07
2.2.3	THDGHGV	TH2	0	0	0	0	0	0	68.52	102.02	146	206.97
2.2.3	TJETAIR	TA	15.22	22.25	64.51	81.75	90.03	121.64	136.85	138.58	0	0
2.2.3	TLPGCAR	TC1	16.57	31.14	31.14	31.14	31.14	20.64	24.42	24.42	24.42	19.27
2.2.3	TLPGCAR	TC2	24.52	46.11	50.36	61.14	76.5	82.14	77.89	95.74	129.65	162.2
2.2.3	TLPGCAR	TC3	5.45	10.24	11.19	13.58	17	18.25	22.64	26.61	34.15	41.38
2.2.3	TLPGCAR	TC4	1.2	2.41	2.41	2.41	2.41	1.49	1.77	1.77	1.77	1.39
2.2.3	TLPGCAR	TCX	6.82	7.57	8.57	8.57	7.62	5.06	2.96	1.76	0	0
2.2.3	TPETCAR	TC1	39.21	30.23	36.38	49.53	60.25	68.19	62.05	67.05	84.03	128.18
2.2.3	TPETCAR	TC2	55.89	43.09	47.19	54.1	58.32	55.14	59.62	70.01	72.77	82.86
2.2.3	TPETCAR	TC3	12.04	9.28	10.16	11.65	12.56	11.88	12.84	15.08	15.67	17.84
2.2.3	TPETCAR	TC4	3.1	2.53	3	3.99	5.08	5.51	6.14	7.09	9.15	12.42

Table A.22. Modal energy consumptions by fuel types in scenario 2.3.2 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
2.3.2	TCNGBUS	TB2	0	3.47	6.71	7.74	5.98	6.02	6.91	4.06	4.39	0
2.3.2	TCNGHGV	TH1	0	0	0	0	1.76	1.76	0	0	0	0
2.3.2	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
2.3.2	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
2.3.2	TDIE	TSDY	0.01	0.02	0.1	0.14	0.19	0.25	0.33	0.42	0.53	0.69
2.3.2	TDIE	TSKT	0.03	0.04	0.29	0.39	0.54	0.68	0.88	1.1	1.39	1.78
2.3.2	TDIE	TSKY	0.63	1.02	4.45	6.18	8.49	11.06	14.69	18.71	23.94	30.92
2.3.2	TDIE	TSTK	0.48	0.78	3.41	4.73	6.57	8.61	11.48	14.7	18.94	24.53
2.3.2	TDIEBUS	TB1	37.39	41.25	30.45	27.63	23.66	18.86	14.17	8.64	4.33	2.33
2.3.2	TDIEBUS	TB2	22.35	23.26	25.16	23.39	20.38	14.66	8.71	6.89	3.81	0
2.3.2	TDIEBUS	TB3	21.03	24.32	23.11	27	27.38	32.39	38	43.72	51.17	60.05
2.3.2	TDIECAR	TC1	5.36	14	13.96	14	14.54	8.11	9.59	11.35	10.81	7.64
2.3.2	TDIECAR	TC2	10.28	26.86	26.78	26.86	27.9	15.56	18.41	21.79	20.74	14.67
2.3.2	TDIECAR	TC3	1.47	3.84	3.83	3.84	3.99	2.22	2.63	3.11	2.96	2.1
2.3.2	TDIECAR	TC4	0.37	0.97	0.97	0.97	1.01	0.56	0.67	0.79	0.75	0.53
2.3.2	TDIECAR	TCX	0.15	0.18	0.16	0.12	0.15	0.07	0.08	0	0	0
2.3.2	TDIEHGV	TH1	153.28	140.72	97.63	95.58	91.49	90.02	37.08	27.77	18.61	9.35
2.3.2	TDIEHGV	TH2	34.91	75.89	52.65	82.04	127.47	157.45	83.75	79.96	66.73	42.35
2.3.2	TDIELGV	TL	25.58	26.16	17.44	14.6	13	11.19	8.71	6.76	4.73	2.49
2.3.2	TDIERAIL	TRF	4.43	4.76	21.6	23.24	24.54	24.15	22.22	17.61	19.71	23.87
2.3.2	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
2.3.2	TELC	TB1	0	0	0.54	2.25	4.15	6.23	8.48	11.12	13.23	10.6
2.3.2	TELC	TB2	0	0	1.13	3.2	6.5	9.78	14.17	18.86	17.68	11.22
2.3.2	TELC	TC1	0	0	0	0	0	0	2.63	2.63	2.63	2.63
2.3.2	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
2.3.2	TELC	TL	0	0	1.06	2.19	3.02	3.91	4.73	5.68	6.7	7.83
2.3.2	TELC	TRF	0.25	0.27	1.7	3.23	5.49	8.1	11.46	17.19	20.6	24.88
2.3.2	TELC	TRH	0	0.13	2.09	3.66	5.62	8.16	9.97	11.76	13.82	16.32
2.3.2	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
2.3.2	TELC	TRMET	0.17	0.3	0.5	0.69	0.92	1.19	1.36	1.55	1.82	2.07
2.3.2	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
2.3.2	THDGAIR	TA	0	0	0	0	0	0	0	0	237.07	369.73
2.3.2	THDGBUS	TB1	0	0	0	0	0	0	0	0	0	5.68
2.3.2	THDGBUS	TB2	0	0	0	0	0	0	0	0	7.49	25.54
2.3.2	THDGHGV	TH1	0	0	0	0	0	0	27.27	31.98	36.44	40.95
2.3.2	THDGHGV	TH2	0	0	0	0	0	0	60.91	90.69	129.78	183.97
2.3.2	TJETAIR	TA	15.22	22.25	96.78	114.45	118.65	149.19	165.63	211.65	41.63	0
2.3.2	TLPGCAR	TC1	16.57	31.14	31.05	31.14	31.14	18.35	21.71	21.71	21.71	56.29
2.3.2	TLPGCAR	TC2	24.52	46.11	45.97	55.53	69.24	72.74	90.65	106.53	136.61	165.35
2.3.2	TLPGCAR	TC3	5.45	10.24	10.21	12.34	15.39	16.17	20.15	23.68	30.36	36.74
2.3.2	TLPGCAR	TC4	1.2	2.41	2.4	2.41	2.41	1.33	1.57	1.57	1.57	1.24
2.3.2	TLPGCAR	TCX	6.82	7.57	8.57	8.57	7.62	5.06	2.96	1.76	0	0
2.3.2	TPETCAR	TC1	39.21	30.24	30.14	39.57	49.13	57	60.02	73.14	88.2	83.55
2.3.2	TPETCAR	TC2	55.89	43.1	42.96	49.15	52.89	48.75	53.07	62.32	64.77	73.49
2.3.2	TPETCAR	TC3	12.04	9.28	9.25	10.59	11.39	10.5	11.43	13.42	13.95	15.83
2.3.2	TPETCAR	TC4	3.1	2.53	2.52	3.39	4.38	4.8	5.48	6.31	8.14	11.11

Table A.23. Modal energy consumptions by fuel types in scenario 2.3.3 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
2.3.3	TCNGBUS	TB2	0	3.47	6.71	7.74	5.98	6.02	6.91	4.06	4.39	0
2.3.3	TCNGHGV	TH1	0	0	19.92	38.93	49.6	63.36	0	0	0	0
2.3.3	TCNGHGV	TH2	0	0	10.74	33.29	68.72	106	0	0	0	0
2.3.3	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
2.3.3	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
2.3.3	TDIE	TSDY	0.01	0.02	0.1	0.14	0.19	0.25	0.33	0.42	0.53	0.69
2.3.3	TDIE	TSKT	0.03	0.04	0.3	0.39	0.54	0.68	0.88	1.1	1.39	1.78
2.3.3	TDIE	TSKY	0.63	1.02	4.45	6.18	8.49	11.06	14.69	18.71	23.94	30.92
2.3.3	TDIE	TSTK	0.48	0.78	3.41	4.73	6.57	8.61	11.48	14.7	18.94	24.53
2.3.3	TDIEBUS	TB1	37.39	41.25	30.45	27.63	23.66	18.86	14.17	8.64	4.33	2.33
2.3.3	TDIEBUS	TB2	22.35	23.26	25.16	23.39	20.38	14.66	8.71	6.89	3.81	0
2.3.3	TDIEBUS	TB3	21.03	24.32	23.11	27	27.38	32.39	38	43.72	51.17	60.05
2.3.3	TDIECAR	TC1	5.36	14	13.96	14	14.54	8.11	9.59	11.35	10.81	7.64
2.3.3	TDIECAR	TC2	10.28	26.86	26.78	26.86	27.9	15.56	18.41	21.79	20.74	14.67
2.3.3	TDIECAR	TC3	1.47	3.84	3.83	3.84	3.99	2.22	2.63	3.11	2.96	2.1
2.3.3	TDIECAR	TC4	0.37	0.97	0.97	0.97	1.01	0.56	0.67	0.79	0.75	0.53
2.3.3	TDIECAR	TCX	0.15	0.18	0.16	0.12	0.15	0.07	0.08	0	0	0
2.3.3	TDIEHGV	TH1	153.28	140.72	84.56	69.99	60.29	49.11	37.32	28.01	18.61	9.35
2.3.3	TDIEHGV	TH2	34.91	75.89	45.6	60.14	82.08	87.02	84.51	79.96	66.73	42.35
2.3.3	TDIELGV	TL	25.58	26.16	17.22	14.38	12.78	11.19	8.71	6.76	4.73	2.49
2.3.3	TDIERAIL	TRF	4.43	4.76	21.6	23.24	24.54	24.07	22.3	17.61	19.71	23.87
2.3.3	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
2.3.3	TELC	TB1	0	0	0.54	2.25	4.15	6.23	8.48	11.12	9.75	7.12
2.3.3	TELC	TB2	0	0	1.13	3.2	6.5	9.78	14.17	18.86	14.46	8
2.3.3	TELC	TC1	0	0	0	0	0	0	3.53	3.53	3.53	3.53
2.3.3	TELC	TC2	0	0	0	0	0	0	5.79	5.79	5.79	5.79
2.3.3	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
2.3.3	TELC	TL	0	0	1.06	2.19	3.02	3.91	4.73	5.68	6.7	7.83
2.3.3	TELC	TRF	0.25	0.27	1.7	3.23	5.49	8.1	11.46	17.19	20.6	24.88
2.3.3	TELC	TRH	0	0.13	2.09	3.66	5.62	8.16	9.97	11.76	13.82	16.32
2.3.3	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
2.3.3	TELC	TRMET	0.17	0.3	0.5	0.69	0.92	1.19	1.36	1.55	1.82	2.07
2.3.3	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
2.3.3	THDGAIR	TA	0	0	0	0	0	0	0	54.14	286.8	369.73
2.3.3	THDGBUS	TB1	0	0	0	0	0	0	0	0	4.68	10.36
2.3.3	THDGBUS	TB2	0	0	0	0	0	0	0	0	11.81	29.86
2.3.3	THDGHGV	TH1	0	0	0	0	0	0	27.27	31.98	36.44	40.95
2.3.3	THDGHGV	TH2	0	0	0	0	0	0	60.91	90.69	129.78	183.97
2.3.3	TJETAIR	TA	15.22	22.25	96.78	114.45	118.65	149.19	165.63	167.49	0	0
2.3.3	TLPGCAR	TC1	16.57	31.14	31.05	31.14	31.14	18.35	21.71	21.71	21.71	17.13
2.3.3	TLPGCAR	TC2	24.52	46.11	45.97	55.53	69.24	72.74	72.74	88.62	118.71	147.44
2.3.3	TLPGCAR	TC3	5.45	10.24	10.21	12.34	15.39	16.17	20.15	23.68	30.36	36.74
2.3.3	TLPGCAR	TC4	1.2	2.41	2.4	2.41	2.41	1.33	1.57	1.57	1.57	1.24
2.3.3	TLPGCAR	TCX	6.82	7.57	8.57	8.57	7.62	5.06	2.96	1.76	0	0
2.3.3	TPETCAR	TC1	39.21	30.24	30.14	39.57	49.13	57	57	71.06	86.12	126.08
2.3.3	TPETCAR	TC2	55.89	43.1	42.96	49.15	52.89	48.75	53.07	62.32	64.77	73.49
2.3.3	TPETCAR	TC3	12.04	9.28	9.25	10.59	11.39	10.5	11.43	13.42	13.95	15.83
2.3.3	TPETCAR	TC4	3.1	2.53	2.52	3.39	4.38	4.8	5.48	6.31	8.14	11.11

Table A.24. Modal energy consumptions by fuel types in scenario 3.2.2 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
3.2.2	TCNGBUS	TB2	0	3.47	6.06	7.05	5.5	5.6	6.42	3.77	4.08	0
3.2.2	TCNGHGV	TH1	0	0	0	0	1.55	1.55	0	0	0	0
3.2.2	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
3.2.2	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
3.2.2	TDIE	TSDY	0.01	0.02	0.07	0.1	0.14	0.19	0.25	0.33	0.43	0.56
3.2.2	TDIE	TSKT	0.03	0.04	0.18	0.25	0.35	0.45	0.61	0.78	1	1.29
3.2.2	TDIE	TSKY	0.63	1.02	3.05	4.41	6.16	8.33	11.43	14.8	19.24	25.16
3.2.2	TDIE	TSTK	0.48	0.78	2.34	3.38	4.77	6.49	8.95	11.65	15.22	19.96
3.2.2	TDIEBUS	TB1	37.39	41.25	34.26	31.08	26.11	21.45	15.7	9.48	4.98	2.62
3.2.2	TDIEBUS	TB2	22.35	23.26	22.71	21.32	18.76	13.64	8.1	6.41	3.54	0
3.2.2	TDIEBUS	TB3	21.03	24.32	22.87	27.75	31.82	35.84	42.37	49.7	56.59	66.71
3.2.2	TDIECAR	TC1	5.36	13.63	14.9	14.9	15.55	9.21	10.76	12.75	12.1	8.65
3.2.2	TDIECAR	TC2	10.28	26.15	28.59	25.38	29.83	17.68	20.65	24.46	23.22	16.6
3.2.2	TDIECAR	TC3	1.47	3.74	4.08	3.63	4.26	2.53	2.95	3.49	3.32	2.37
3.2.2	TDIECAR	TC4	0.37	0.95	1.04	1.04	1.08	0.64	0.75	0.89	0.84	0.6
3.2.2	TDIECAR	TCX	0.15	0.18	0.14	0.11	0.13	0.08	0.08	0	0	0
3.2.2	TDIEHGV	TH1	153.28	140.72	109.84	107.53	103.21	101.56	41.72	31.25	20.94	10.52
3.2.2	TDIEHGV	TH2	34.91	75.89	59.23	92.29	142.62	177.44	95.07	89.95	75.07	47.64
3.2.2	TDIELGV	TL	25.58	26.16	18.51	16.02	14.43	12.64	9.64	7.6	5.33	2.8
3.2.2	TDIERAIL	TRF	4.43	4.76	13.28	14.04	14.44	14.14	12.86	10.1	11.19	13.41
3.2.2	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
3.2.2	TELC	TB1	0	0	0.61	2.54	4.67	7.01	9.54	12.51	14.88	16.68
3.2.2	TELC	TB2	0	0	1.02	2.92	5.98	9.1	13.19	17.55	21.64	20.19
3.2.2	TELC	TC1	0	0	0	0	0	0	3.86	3.86	3.86	3.86
3.2.2	TELC	TC2	0	0	1.63	1.63	1.63	1.63	0	0	0	0
3.2.2	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
3.2.2	TELC	TL	0	0	1.2	2.46	3.39	4.39	5.33	6.39	7.54	8.81
3.2.2	TELC	TRF	0.25	0.27	1.05	1.95	3.24	4.73	6.64	9.87	11.7	13.97
3.2.2	TELC	TRH	0	0.13	1.17	2.08	3.21	4.72	5.99	7.16	8.52	10.19
3.2.2	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
3.2.2	TELC	TRMET	0.17	0.3	0.46	0.59	0.75	0.92	1.04	1.17	1.38	1.55
3.2.2	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
3.2.2	THDGAIR	TA	0	0	0	0	0	0	0	0	207.15	321.55
3.2.2	THDGBUS	TB2	0	0	0	0	0	0	0	0	0	10.67
3.2.2	THDGHGV	TH1	0	0	0	0	0	0	30.68	35.97	41	46.07
3.2.2	THDGHGV	TH2	0	0	0	0	0	0	68.52	102.02	146	206.97
3.2.2	TJETAIR	TA	15.22	22.25	64.51	81.75	90.03	121.64	136.85	178.13	32.13	0
3.2.2	TLPGCAR	TC1	16.57	31.14	26.75	43.14	43.14	21.48	24.16	24.16	24.16	71.62
3.2.2	TLPGCAR	TC2	24.52	47.43	34.32	61.41	81.75	78.81	100.23	118.84	154.17	187.23
3.2.2	TLPGCAR	TC3	5.45	10.46	7.9	13.92	17.22	17.45	22.3	26.43	34.28	41.57
3.2.2	TLPGCAR	TC4	1.2	2.41	2.01	3.28	3.28	1.55	1.75	1.75	1.75	1.43
3.2.2	TLPGCAR	TCX	6.82	7.57	7.61	7.61	6.78	5.36	2.89	1.72	0	0
3.2.2	TPETCAR	TC1	39.21	30.23	36.89	36.89	48.8	64.66	64.02	80.27	97.41	86.39
3.2.2	TPETCAR	TC2	55.89	43.09	47.19	47.19	51	54.8	59.28	70.16	72.95	82.56
3.2.2	TPETCAR	TC3	12.04	9.28	11.29	11.29	12.88	12.95	12.79	15.13	15.66	17.78
3.2.2	TPETCAR	TC4	3.1	2.53	3.04	3.04	4.11	5.12	5.73	6.97	9.03	12.6

Table A.25. Modal energy consumptions by fuel types in scenario 3.2.3 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
3.2.3	TCNGBUS	TB2	0	3.47	6.06	7.05	5.5	5.6	6.42	3.77	4.08	0
3.2.3	TCNGHGV	TH1	0	0	0	42.56	56.23	69.27	0	0	0	0
3.2.3	TCNGHGV	TH2	0	0	0	25.36	76.01	89.4	0	0	0	0
3.2.3	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
3.2.3	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
3.2.3	TDIE	TSDY	0.01	0.02	0.07	0.1	0.14	0.19	0.25	0.33	0.43	0.56
3.2.3	TDIE	TSKT	0.03	0.04	0.18	0.25	0.35	0.45	0.61	0.78	1	1.29
3.2.3	TDIE	TSKY	0.63	1.02	3.05	4.41	6.16	8.33	11.43	14.8	19.24	25.16
3.2.3	TDIE	TSTK	0.48	0.78	2.34	3.38	4.77	6.49	8.95	11.65	15.22	19.96
3.2.3	TDIEBUS	TB1	37.39	41.25	34.26	31.08	26.49	21.27	15.88	9.66	4.98	2.62
3.2.3	TDIEBUS	TB2	22.35	23.26	22.71	21.32	18.76	13.64	8.1	6.41	3.54	0
3.2.3	TDIEBUS	TB3	21.03	24.32	22.87	27.75	31.82	35.84	42.37	49.7	56.59	66.71
3.2.3	TDIECAR	TC1	5.36	13.63	14.75	14.75	15.33	8.15	9.52	11.27	10.7	7.65
3.2.3	TDIECAR	TC2	10.28	26.15	28.31	25.1	29.4	15.64	18.27	21.64	20.54	14.69
3.2.3	TDIECAR	TC3	1.47	3.84	4.14	4.14	4.3	2.23	2.61	3.09	2.93	2.1
3.2.3	TDIECAR	TC4	0.37	0.97	1.05	1.05	1.09	0.57	0.66	0.79	0.75	0.53
3.2.3	TDIECAR	TCX	0.15	0.18	0.14	0.11	0.13	0.08	0.08	0	0	0
3.2.3	TDIEHGV	TH1	153.28	140.72	109.84	78.74	67.83	55.24	41.98	31.51	20.94	10.52
3.2.3	TDIEHGV	TH2	34.91	75.89	59.23	75.58	92.34	118.17	95.07	89.95	75.07	47.64
3.2.3	TDIELGV	TL	25.58	26.16	18.51	16.02	14.43	12.64	9.64	7.6	5.33	2.8
3.2.3	TDIERAIL	TRF	4.43	4.76	13.28	14.04	14.46	14.07	12.92	10.1	11.19	13.41
3.2.3	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
3.2.3	TELC	TB1	0	0	0.61	2.54	4.67	7.01	9.54	12.51	14.88	16.68
3.2.3	TELC	TB2	0	0	1.02	2.92	5.98	9.1	13.19	17.55	21.64	16.41
3.2.3	TELC	TC1	0	0	0	0	0	0	3.86	7.64	7.64	7.64
3.2.3	TELC	TC2	0	0	1.63	1.63	1.63	1.63	0	0	0	0
3.2.3	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
3.2.3	TELC	TL	0	0	1.2	2.46	3.39	4.39	5.33	6.39	7.54	8.81
3.2.3	TELC	TRF	0.25	0.27	1.05	1.95	3.24	4.73	6.64	9.87	11.7	13.97
3.2.3	TELC	TRH	0	0.13	1.17	2.08	3.21	4.72	5.99	7.16	8.52	10.19
3.2.3	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
3.2.3	TELC	TRMET	0.17	0.3	0.46	0.59	0.75	0.92	1.04	1.17	1.38	1.55
3.2.3	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
3.2.3	THDGAIR	TA	0	0	0	0	0	0	46.31	96.91	245.53	321.55
3.2.3	THDGBUS	TB2	0	0	0	0	0	0	0	0	0	15.75
3.2.3	THDGHGV	TH1	0	0	0	0	0	0	30.68	35.97	41	46.07
3.2.3	THDGHGV	TH2	0	0	0	0	0	0	68.52	102.02	146	206.97
3.2.3	TJETAIR	TA	15.22	22.25	64.51	81.75	90.03	121.64	99.07	99.07	0	0
3.2.3	TLPGCAR	TC1	16.57	31.14	25.37	41.76	41.76	19.01	21.37	21.37	47	88.98
3.2.3	TLPGCAR	TC2	24.52	46.11	35.78	62.87	69.37	69.04	89.01	105.48	136.35	165.15
3.2.3	TLPGCAR	TC3	5.45	10.24	8.34	13.73	15.38	15.3	19.82	23.48	30.27	36.67
3.2.3	TLPGCAR	TC4	1.2	2.41	1.91	3.18	3.18	1.38	1.55	1.55	1.55	1.27
3.2.3	TLPGCAR	TCX	6.82	7.57	7.61	7.61	6.78	5.36	2.89	1.72	0	0
3.2.3	TPETCAR	TC1	39.21	30.23	36.56	36.56	47.58	60.22	59.21	65.97	63.07	51.23
3.2.3	TPETCAR	TC2	55.89	43.09	46.71	46.71	56.41	48.63	52.59	62.22	64.1	73.03
3.2.3	TPETCAR	TC3	12.04	9.28	11.19	11.19	13.28	11.6	11.33	13.4	13.8	15.73
3.2.3	TPETCAR	TC4	3.1	2.53	3.01	3.01	4.02	4.77	5.35	6.52	8.57	12.07

Table A.26. Modal energy consumptions by fuel types in scenario 3.3.2 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
3.3.2	TCNGBUS	TB2	0	3.47	6.71	7.74	5.98	6.02	6.91	4.06	4.39	0
3.3.2	TCNGHGV	TH1	0	0	0	0	1.76	1.76	0	0	0	0
3.3.2	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
3.3.2	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
3.3.2	TDIE	TSDY	0.01	0.02	0.1	0.14	0.19	0.25	0.33	0.42	0.53	0.69
3.3.2	TDIE	TSKT	0.03	0.04	0.29	0.39	0.54	0.68	0.88	1.1	1.39	1.78
3.3.2	TDIE	TSKY	0.63	1.02	4.45	6.18	8.49	11.06	14.69	18.71	23.94	30.92
3.3.2	TDIE	TSTK	0.48	0.78	3.41	4.73	6.57	8.61	11.48	14.7	18.94	24.53
3.3.2	TDIEBUS	TB1	37.39	41.25	30.45	27.63	23.21	19.06	13.95	8.43	4.42	2.33
3.3.2	TDIEBUS	TB2	22.35	23.26	25.16	23.39	20.38	14.66	8.71	6.89	3.81	0
3.3.2	TDIEBUS	TB3	21.03	24.32	20.33	24.67	28.28	31.86	37.66	44.17	50.31	59.3
3.3.2	TDIECAR	TC1	5.36	13.63	13.59	12.11	14.18	8.11	9.59	11.35	10.81	7.64
3.3.2	TDIECAR	TC2	10.28	26.48	23.27	20.42	24.82	16.18	18.18	21.56	21.56	15.06
3.3.2	TDIECAR	TC3	1.47	3.74	3.73	3.32	3.89	2.22	2.63	3.11	2.96	2.1
3.3.2	TDIECAR	TC4	0.37	0.95	0.95	0.95	0.99	0.56	0.67	0.79	0.75	0.53
3.3.2	TDIECAR	TCX	0.15	0.18	0.14	0.11	0.13	0.08	0.08	0	0	0
3.3.2	TDIEHGV	TH1	153.28	140.72	97.63	95.58	91.49	90.02	37.08	27.77	18.61	9.35
3.3.2	TDIEHGV	TH2	34.91	75.89	52.65	82.04	126.78	157.73	84.51	79.96	66.73	42.35
3.3.2	TDIELGV	TL	25.58	26.16	16.45	14.24	12.83	11.24	8.57	6.76	4.73	2.49
3.3.2	TDIERAIL	TRF	4.43	4.76	21.6	23.24	24.5	24.19	22.19	17.61	19.71	23.87
3.3.2	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
3.3.2	TELC	TB1	0	0	0.54	2.25	4.15	6.23	8.48	11.12	8.51	5.89
3.3.2	TELC	TB2	0	0	1.13	3.2	6.5	9.78	14.17	16.2	11.8	5.33
3.3.2	TELC	TC1	0	0	0	0	0	0	3.61	3.61	3.61	3.61
3.3.2	TELC	TC2	0	0	1.45	1.45	1.45	1.45	6.54	6.54	6.54	6.54
3.3.2	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
3.3.2	TELC	TL	0	0	1.06	2.19	3.02	3.91	4.73	5.68	6.7	7.83
3.3.2	TELC	TRF	0.25	0.27	1.7	3.23	5.49	8.1	11.46	17.19	20.6	24.88
3.3.2	TELC	TRH	0	0.13	2.09	3.66	5.62	8.16	9.97	11.76	13.82	16.32
3.3.2	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
3.3.2	TELC	TRMET	0.17	0.3	0.5	0.69	0.92	1.19	1.36	1.55	1.82	2.07
3.3.2	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
3.3.2	THDGAIR	TA	0	0	0	0	0	0	0	0	240.63	369.73
3.3.2	THDGBUS	TB1	0	0	0	0	0	0	0	0	6.33	12.01
3.3.2	THDGBUS	TB2	0	0	0	0	0	0	0	3.66	15.47	33.52
3.3.2	THDGHGV	TH1	0	0	0	0	0	0	27.27	31.98	36.44	40.95
3.3.2	THDGHGV	TH2	0	0	0	0	0	0	60.91	90.69	129.78	183.97
3.3.2	TJETAIR	TA	15.22	22.25	96.78	114.45	118.65	149.19	165.63	211.65	38.65	0
3.3.2	TLPGCAR	TC1	16.57	32.17	20.68	36.85	52.58	20.41	21.27	21.27	21.27	68.05
3.3.2	TLPGCAR	TC2	24.52	47.65	30.51	54.45	77.74	70.06	68.88	85.42	115.95	146.21
3.3.2	TLPGCAR	TC3	5.45	10.59	6.78	12.1	17.27	15.57	19.8	23.48	30.44	36.98
3.3.2	TLPGCAR	TC4	1.2	2.41	1.5	2.61	3.89	1.48	1.54	1.54	1.54	1.54
3.3.2	TLPGCAR	TCX	6.82	7.57	7.61	7.61	6.78	5.36	2.89	1.72	0	0
3.3.2	TPETCAR	TC1	39.21	30.24	33.5	33.6	33.6	56.42	56.08	70.53	87	73.54
3.3.2	TPETCAR	TC2	55.89	43.1	42.96	43.1	43.1	48.38	52.69	62.36	65.16	73.23
3.3.2	TPETCAR	TC3	12.04	9.28	10.26	10.29	10.29	11.43	11.35	13.43	14.03	15.77
3.3.2	TPETCAR	TC4	3.1	2.53	2.77	2.78	2.78	4.33	4.92	6.02	7.94	10.89

Table A.27. Modal energy consumptions by fuel types in scenario 3.3.3 (PJ).

Scenario	Fuel	Vehicle	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
3.3.3	TCNGBUS	TB2	0	3.47	6.71	7.74	5.98	6.02	6.91	4.06	4.39	0
3.3.3	TCNGHGV	TH1	0	0	0	37.83	49.98	49.94	0	0	0	0
3.3.3	TCNGHGV	TH2	0	0	0	22.54	67.56	67.56	0	0	0	0
3.3.3	TDIE	TIDOF	1.41	1.6	1.78	1.91	1.82	1.97	2.12	2.29	2.46	2.66
3.3.3	TDIE	TIDOP	1.11	1.32	1.56	1.85	2.14	2.55	3.02	3.6	4.26	5.06
3.3.3	TDIE	TSDY	0.01	0.02	0.1	0.14	0.19	0.25	0.33	0.42	0.53	0.69
3.3.3	TDIE	TSKT	0.03	0.04	0.29	0.39	0.54	0.68	0.88	1.1	1.39	1.78
3.3.3	TDIE	TSKY	0.63	1.02	4.45	6.18	8.49	11.06	14.69	18.71	23.94	30.92
3.3.3	TDIE	TSTK	0.48	0.78	3.41	4.73	6.57	8.61	11.48	14.7	18.94	24.53
3.3.3	TDIEBUS	TB1	37.39	41.25	30.45	27.63	23.21	19.06	13.95	8.43	4.42	2.33
3.3.3	TDIEBUS	TB2	22.35	23.26	25.16	23.39	20.38	14.66	8.71	6.89	3.81	0
3.3.3	TDIEBUS	TB3	21.03	24.32	20.33	24.67	28.28	31.86	37.66	44.17	50.31	59.3
3.3.3	TDIECAR	TC1	5.36	13.63	13.59	12.11	14.11	7.17	8.49	10.04	9.56	6.76
3.3.3	TDIECAR	TC2	10.28	26.2	25.61	22.76	27.16	13.81	16.24	19.23	19.23	13.02
3.3.3	TDIECAR	TC3	1.47	3.74	3.73	3.32	3.87	1.97	2.33	2.75	2.62	1.85
3.3.3	TDIECAR	TC4	0.37	0.95	0.95	0.95	0.98	0.5	0.59	0.7	0.67	0.47
3.3.3	TDIECAR	TCX	0.15	0.18	0.14	0.11	0.13	0.08	0.08	0	0	0
3.3.3	TDIEHGV	TH1	153.28	140.72	97.63	69.99	60.29	58.85	37.08	27.77	18.61	9.35
3.3.3	TDIEHGV	TH2	34.91	75.89	52.65	67.18	82.08	113.03	84.51	79.96	66.73	42.35
3.3.3	TDIELGV	TL	25.58	26.16	16.45	14.24	12.83	11.24	8.57	6.76	4.73	2.49
3.3.3	TDIERAIL	TRF	4.43	4.76	21.6	23.24	24.51	24.19	22.19	17.61	19.71	23.87
3.3.3	TDIERAIL	TRM	2.37	2.38	2.07	1.91	1.66	1.44	1.21	0.91	0.81	0.82
3.3.3	TELC	TB1	0	0	0.54	2.25	4.15	6.23	8.48	11.12	11.49	8.87
3.3.3	TELC	TB2	0	0	1.13	3.2	6.5	9.78	14.17	18.86	14.46	8
3.3.3	TELC	TC1	0	0	0	0	0	0	3.43	3.43	3.43	3.43
3.3.3	TELC	TC2	0	0	1.45	1.45	1.45	1.45	0	0	0	0
3.3.3	TELC	TCX	0	0	0.08	0.5	1.19	2.13	3.31	4.39	5.67	6.64
3.3.3	TELC	TL	0	0	1.06	2.19	3.02	3.91	4.73	5.68	6.7	7.83
3.3.3	TELC	TRF	0.25	0.27	1.7	3.23	5.49	8.1	11.46	17.19	20.6	24.88
3.3.3	TELC	TRH	0	0.13	2.09	3.66	5.62	8.16	9.97	11.76	13.82	16.32
3.3.3	TELC	TRM	0.45	0.45	0.54	0.61	0.68	0.75	0.81	0.94	0.94	0.89
3.3.3	TELC	TRMET	0.17	0.3	0.5	0.69	0.92	1.19	1.36	1.55	1.82	2.07
3.3.3	TELC	TRS	0.25	0.26	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.52
3.3.3	THDGAIR	TA	0	0	0	0	0	0	76.18	132.59	286.8	369.73
3.3.3	THDGBUS	TB1	0	0	0	0	0	0	0	0	2.33	8.01
3.3.3	THDGBUS	TB2	0	0	0	0	0	0	0	0	11.81	29.86
3.3.3	THDGHGV	TH1	0	0	0	0	0	0	27.27	31.98	36.44	40.95
3.3.3	THDGHGV	TH2	0	0	0	0	0	0	60.91	90.69	129.78	183.97
3.3.3	TJETAIR	TA	15.22	22.25	96.78	114.45	118.65	145.6	103.49	103.49	0	0
3.3.3	TLPGCAR	TC1	16.57	31.44	21.77	37.94	42.45	17	18.96	18.96	38.34	79.17
3.3.3	TLPGCAR	TC2	24.52	46.11	27.12	51.06	72.83	61.95	78.82	93.46	120.46	147.21
3.3.3	TLPGCAR	TC3	5.45	10.24	6.03	11.34	16.18	13.77	17.52	20.77	26.93	32.72
3.3.3	TLPGCAR	TC4	1.2	2.41	1.8	2.92	2.92	1.21	1.38	1.38	1.38	1.12
3.3.3	TLPGCAR	TCX	6.82	7.57	7.61	7.61	6.78	5.36	2.89	1.72	0	0
3.3.3	TPETCAR	TC1	39.21	30.24	33.5	33.6	40.2	53.14	52.45	66.11	66.69	53.1
3.3.3	TPETCAR	TC2	55.89	43.1	42.96	43.1	43.1	42.8	46.62	55.17	57.65	64.77
3.3.3	TPETCAR	TC3	12.04	9.28	10.26	10.29	10.29	10.23	10.04	11.88	12.41	13.95
3.3.3	TPETCAR	TC4	3.1	2.53	2.77	2.78	3.53	4.09	4.62	5.65	7.63	10.72

APPENDIX B: SHARE OF SECTORS IN TOTAL CO_2 EMISSIONS AND ENERGY CONSUMPTIONS BY SCENARIOS

Table B.1. Share of sectors in total CO_2 emissions by scenarios (%).

Scenario	Sector	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
BASE	Energy	36.4	29.4	34.8	34.1	38.7	41.6	44.6	46.9	47.2	47.6
	Industrial	33.1	33.1	32.2	35.3	34.9	34.8	36.1	36.8	38.7	40.7
	Residential	10.5	13.9	14.1	12.6	10.7	9.7	7.7	5.9	4.8	3.9
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	12.0	9.2	8.3	7.3	6.1	4.4	3.8	3.4	3.1
	Others	4.9	10.3	8.3	8.1	6.8	6.2	5.6	4.8	4.0	2.8
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
211	Energy	36.4	29.5	35.3	34.7	38.8	42.0	45.0	47.3	47.6	47.9
	Industrial	33.1	33.1	32.7	35.7	35.5	35.1	36.2	37.0	38.9	40.9
	Residential	10.5	14.0	14.3	12.8	10.8	9.8	7.7	6.0	4.8	3.9
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	11.9	8.0	7.2	6.3	5.2	3.7	3.2	2.9	2.6
	Others	4.9	10.3	8.4	8.2	6.9	6.3	5.6	4.9	4.0	2.8
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
311	Energy	36.4	29.5	35.6	35.1	39.4	42.4	45.4	47.6	48.4	48.6
	Industrial	33.1	33.1	32.9	36.1	35.8	35.4	36.5	37.1	38.7	40.7
	Residential	10.5	14.0	14.4	12.9	10.9	9.9	7.7	6.0	4.8	3.9
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	11.9	7.2	6.0	5.2	4.3	3.1	2.7	2.4	2.2
	Others	4.9	10.3	8.4	8.3	7.0	6.3	5.6	4.9	4.0	2.8
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
121	Energy	36.4	29.4	34.8	34.2	38.6	41.7	44.6	46.9	47.2	47.6
	Industrial	33.1	33.1	32.2	35.3	35.1	34.8	36.2	36.9	38.8	40.7
	Residential	10.5	13.9	14.1	12.6	10.7	9.8	7.7	6.0	4.8	3.9
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	12.0	9.2	8.2	7.1	5.9	4.3	3.7	3.3	3.0
	Others	4.9	10.3	8.3	8.2	6.9	6.3	5.6	4.9	4.1	2.8
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
131	Energy	36.4	29.4	35.0	34.3	38.5	41.9	44.5	46.9	47.2	47.7
	Industrial	33.1	33.1	32.1	35.3	35.2	34.9	36.3	36.9	38.8	40.7
	Residential	10.5	13.9	14.1	12.6	10.8	9.8	7.7	6.0	4.8	3.9
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	12.0	9.1	8.1	6.9	5.7	4.2	3.6	3.2	3.0
	Others	4.9	10.3	8.3	8.2	7.0	6.2	5.7	4.9	4.1	2.8
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
112	Energy	36.4	29.4	34.9	34.0	38.6	41.6	44.7	47.2	48.6	49.2
	Industrial	33.1	33.1	32.1	35.3	34.9	34.9	36.2	37.0	38.5	40.2
	Residential	10.5	14.0	14.1	12.6	10.6	9.7	7.7	6.0	4.8	3.9
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	12.0	9.0	8.2	7.2	5.8	4.0	3.2	2.4	2.2
	Others	4.9	10.3	8.4	8.4	7.1	6.3	5.7	4.9	4.0	2.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table B.1. Share of sectors in total CO_2 emissions by scenarios (%) cont.

Scenario	Sector	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
113	Energy	36.4	29.4	34.8	34.0	38.7	42.2	45.2	47.9	49.3	49.3
	Industrial	33.1	33.1	32.2	35.2	35.0	35.3	36.6	36.9	38.3	40.2
	Residential	10.5	13.9	14.1	12.6	10.7	9.9	7.8	6.0	4.8	3.9
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	12.0	9.0	8.2	6.8	4.8	3.1	2.6	1.9	2.0
	Others	4.9	10.3	8.5	8.4	7.2	6.3	5.7	4.8	3.9	2.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
122	Energy	36.4	29.4	34.8	34.1	38.5	41.8	44.7	47.1	48.8	49.4
	Industrial	33.1	33.1	32.2	35.2	35.1	34.9	36.2	36.9	38.4	40.0
	Residential	10.5	13.9	14.1	12.6	10.7	9.8	7.7	6.0	4.8	3.9
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	12.0	9.0	8.1	7.0	5.6	4.0	3.4	2.3	2.1
	Others	4.9	10.3	8.5	8.4	7.2	6.3	5.7	4.9	3.9	2.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
123	Energy	36.4	29.4	34.7	34.1	38.7	42.1	45.2	47.9	49.4	49.5
	Industrial	33.1	33.1	32.2	35.1	34.9	35.1	36.4	36.8	38.2	40.0
	Residential	10.5	13.9	14.0	12.6	10.6	9.8	7.7	6.0	4.7	3.9
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	12.0	9.0	8.2	7.1	5.1	3.3	2.8	2.0	2.1
	Others	4.9	10.3	8.6	8.4	7.1	6.3	5.7	4.8	3.9	2.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
132	Energy	36.4	29.4	34.7	34.2	38.3	41.9	44.7	47.0	49.1	49.6
	Industrial	33.1	33.1	32.2	35.2	35.3	35.0	36.3	37.0	38.2	39.9
	Residential	10.5	13.9	14.0	12.6	10.7	9.8	7.7	6.0	4.7	3.8
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.8
	Transport	13.9	12.0	8.9	8.0	6.8	5.4	3.9	3.4	2.3	2.1
	Others	4.9	10.3	8.7	8.4	7.2	6.4	5.7	4.9	3.9	2.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
133	Energy	36.4	29.4	34.8	34.2	38.4	42.0	44.9	47.7	49.8	49.6
	Industrial	33.1	33.1	32.2	35.1	35.2	35.0	36.4	36.8	37.9	39.9
	Residential	10.5	13.9	14.0	12.6	10.7	9.8	7.7	5.9	4.7	3.8
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.8
	Transport	13.9	11.9	8.9	8.1	6.9	5.3	3.6	3.1	2.0	2.1
	Others	4.9	10.3	8.6	8.4	7.2	6.3	5.7	4.8	3.8	2.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
212	Energy	36.4	29.5	35.3	34.5	39.1	42.0	45.0	47.4	49.0	49.2
	Industrial	33.1	33.1	32.6	35.6	35.3	35.1	36.5	37.1	38.4	40.2
	Residential	10.5	14.0	14.3	12.8	10.8	9.8	7.7	6.0	4.8	3.9
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	11.9	8.0	7.2	6.2	5.2	3.3	2.9	2.1	2.2
	Others	4.9	10.3	8.4	8.4	7.1	6.3	5.7	4.9	3.9	2.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
213	Energy	36.4	29.5	35.3	34.5	39.3	42.4	45.4	48.1	49.3	49.4
	Industrial	33.1	33.1	32.6	35.6	35.5	35.4	36.7	37.1	38.3	40.2
	Residential	10.5	14.0	14.3	12.8	10.8	9.9	7.8	6.0	4.8	3.9
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	11.9	8.0	7.2	5.6	4.3	2.7	2.3	1.9	2.0
	Others	4.9	10.3	8.4	8.4	7.2	6.3	5.7	4.8	3.9	2.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table B.1. Share of sectors in total CO_2 emissions by scenarios (%) cont.

Scenario	Sector	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
312	Energy	36.4	29.5	35.7	35.0	39.4	42.3	45.3	47.5	49.0	49.2
	Industrial	33.1	33.1	32.8	36.1	35.7	35.4	36.7	37.2	38.4	40.2
	Residential	10.5	14.0	14.4	12.9	10.9	9.9	7.8	6.0	4.8	3.9
	Service	1.2	1.3	1.5	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	11.9	7.2	6.0	5.2	4.3	2.8	2.7	2.1	2.1
	Others	4.9	10.3	8.4	8.5	7.2	6.4	5.7	4.9	3.9	2.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
313	Energy	36.4	29.5	35.7	35.0	39.9	42.5	45.7	48.3	49.0	49.4
	Industrial	33.1	33.1	32.8	36.0	35.4	35.5	36.7	37.0	38.5	40.2
	Residential	10.5	14.0	14.4	12.9	10.8	9.9	7.8	6.0	4.8	3.9
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	11.9	7.2	6.0	5.2	4.1	2.5	2.2	2.0	2.0
	Others	4.9	10.3	8.4	8.5	7.1	6.3	5.7	4.8	3.9	2.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
221	Energy	36.4	29.5	35.3	34.7	38.6	41.9	44.9	47.1	47.5	47.9
	Industrial	33.1	33.1	32.6	35.6	35.5	35.1	36.3	37.0	38.9	40.9
	Residential	10.5	14.0	14.3	12.7	10.9	9.8	7.7	6.0	4.8	3.9
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	11.9	8.0	7.1	6.3	5.2	3.7	3.3	2.9	2.6
	Others	4.9	10.3	8.4	8.2	7.0	6.3	5.7	4.9	4.1	2.8
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
231	Energy	36.4	29.5	35.4	34.7	38.7	42.0	44.8	47.1	47.7	48.1
	Industrial	33.1	33.1	32.5	35.6	35.5	35.1	36.4	37.0	38.8	40.7
	Residential	10.5	14.0	14.3	12.7	10.9	9.8	7.7	6.0	4.8	3.9
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	11.9	8.0	7.1	6.3	5.2	3.7	3.3	2.9	2.6
	Others	4.9	10.3	8.4	8.3	7.1	6.3	5.7	4.9	4.0	2.8
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
321	Energy	36.4	29.5	35.7	35.1	39.2	42.5	45.3	47.6	48.5	48.7
	Industrial	33.1	33.1	32.8	36.1	35.8	35.4	36.5	37.1	38.6	40.6
	Residential	10.5	14.0	14.4	12.9	10.9	9.9	7.7	6.0	4.8	3.9
	Service	1.2	1.3	1.5	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	11.9	7.3	6.0	5.2	4.3	3.1	2.7	2.4	2.2
	Others	4.9	10.2	8.4	8.3	7.1	6.3	5.7	4.9	4.0	2.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
331	Energy	36.4	29.5	35.6	35.1	39.0	42.3	45.2	47.6	48.6	48.9
	Industrial	33.1	33.1	32.7	36.0	36.0	35.4	36.5	37.1	38.5	40.5
	Residential	10.5	14.0	14.4	12.9	11.0	9.9	7.8	6.0	4.8	3.9
	Service	1.2	1.3	1.5	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	11.9	7.3	6.0	5.2	4.3	3.1	2.7	2.4	2.2
	Others	4.9	10.2	8.5	8.4	7.2	6.3	5.7	4.9	4.0	2.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
222	Energy	36.4	29.5	35.4	34.5	38.8	42.0	45.0	47.3	49.2	49.4
	Industrial	33.1	33.1	32.5	35.6	35.4	35.1	36.5	37.1	38.3	40.0
	Residential	10.5	14.0	14.3	12.7	10.8	9.8	7.8	6.0	4.8	3.9
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	11.9	8.0	7.2	6.3	5.2	3.3	3.0	2.1	2.1
	Others	4.9	10.3	8.4	8.4	7.2	6.3	5.7	4.9	3.9	2.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table B.1. Share of sectors in total CO_2 emissions by scenarios (%) cont.

Scenario	Sector	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
223	Energy	36.4	29.5	35.3	34.5	39.0	42.3	45.4	48.0	49.6	49.6
	Industrial	33.1	33.1	32.5	35.6	35.5	35.2	36.6	36.9	38.1	40.0
	Residential	10.5	14.0	14.3	12.7	10.8	9.9	7.8	6.0	4.7	3.9
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	11.9	8.0	7.1	5.9	4.7	2.9	2.5	2.0	2.1
	Others	4.9	10.3	8.4	8.4	7.2	6.3	5.7	4.8	3.9	2.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
232	Energy	36.4	29.5	35.3	34.5	38.6	42.0	44.9	47.2	49.3	49.6
	Industrial	33.1	33.1	32.5	35.6	35.5	35.0	36.5	37.1	38.1	39.9
	Residential	10.5	14.0	14.3	12.7	10.8	9.8	7.8	6.0	4.7	3.8
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.8
	Transport	13.9	11.9	8.0	7.1	6.3	5.2	3.4	3.1	2.1	2.1
	Others	4.9	10.3	8.5	8.4	7.2	6.4	5.7	4.9	3.9	2.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
233	Energy	36.4	29.4	35.3	34.6	38.7	42.2	45.1	47.8	49.7	49.7
	Industrial	33.1	33.2	32.5	35.5	35.5	35.2	36.5	36.9	37.9	39.8
	Residential	10.5	13.9	14.3	12.7	10.8	9.9	7.8	6.0	4.7	3.8
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.7	1.8
	Transport	13.9	11.9	8.0	7.1	6.1	4.8	3.2	2.8	2.0	2.1
	Others	4.9	10.3	8.5	8.4	7.2	6.3	5.7	4.8	3.9	2.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
322	Energy	36.4	29.5	35.5	35.0	39.2	42.4	45.2	47.5	49.2	49.4
	Industrial	33.1	33.1	32.9	36.0	35.8	35.4	36.6	37.2	38.3	40.0
	Residential	10.5	14.0	14.4	12.9	10.9	9.9	7.8	6.0	4.8	3.9
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	11.9	7.2	6.0	5.2	4.3	3.0	2.7	2.1	2.1
	Others	4.9	10.3	8.5	8.5	7.2	6.4	5.7	4.9	3.9	2.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
323	Energy	36.4	29.5	35.6	35.0	39.5	42.6	46.0	48.5	49.4	49.6
	Industrial	33.1	33.1	32.9	36.0	35.7	35.5	36.5	36.8	38.2	40.0
	Residential	10.5	14.0	14.4	12.9	10.9	9.9	7.7	6.0	4.7	3.9
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	11.9	7.2	6.0	5.2	4.0	2.5	2.2	2.0	2.0
	Others	4.9	10.3	8.5	8.5	7.2	6.3	5.6	4.8	3.9	2.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
332	Energy	36.4	29.5	35.6	35.1	39.0	42.3	45.1	47.4	49.5	49.7
	Industrial	33.1	33.1	32.8	36.0	35.9	35.4	36.6	37.3	38.1	39.8
	Residential	10.5	14.0	14.4	12.9	11.0	9.9	7.8	6.0	4.7	3.8
	Service	1.2	1.3	1.4	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	11.9	7.2	6.0	5.2	4.3	3.1	2.7	2.1	2.1
	Others	4.9	10.3	8.5	8.5	7.2	6.4	5.7	4.9	3.9	2.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
333	Energy	36.4	29.5	35.6	35.1	39.1	42.6	46.2	48.7	49.7	49.7
	Industrial	33.1	33.2	32.7	36.0	35.9	35.5	36.3	36.7	38.0	39.9
	Residential	10.5	14.0	14.4	12.9	10.9	9.9	7.7	5.9	4.7	3.9
	Service	1.2	1.3	1.5	1.6	1.6	1.6	1.7	1.7	1.8	1.9
	Transport	13.9	11.9	7.2	6.0	5.2	4.0	2.5	2.2	2.0	2.0
	Others	4.9	10.3	8.5	8.4	7.2	6.3	5.6	4.8	3.9	2.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table B.2. Share of sectors in total energy consumptions by scenarios (%).

Scenario	Sector	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
BASE	Agricultural	0.5	0.4	0.4	0.3	59.9	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.8	7.1	3.0	8.0	8.6	9.0	9.5	9.9
	Industrial	42.9	41.3	43.2	45.3	19.2	50.8	54.6	57.7	60.7	63.3
	Residential	30.2	34.9	35.0	33.8	12.8	29.6	26.7	23.7	20.9	18.4
	Transport	18.9	16.9	14.7	13.4	5.1	11.3	9.8	9.2	8.6	8.2
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
211	Agricultural	0.5	0.4	0.4	0.3	60.0	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.8	7.2	3.0	8.0	8.6	9.1	9.5	9.9
	Industrial	42.9	41.4	43.5	45.5	19.2	51.0	55.0	58.0	61.0	63.5
	Residential	30.2	34.9	35.1	33.9	12.9	29.8	26.9	23.8	21.0	18.4
	Transport	18.9	16.8	14.2	13.0	4.9	10.8	9.1	8.8	8.1	7.9
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
311	Agricultural	0.5	0.4	0.4	0.3	59.9	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.9	7.2	3.0	8.0	8.6	9.1	9.5	9.9
	Industrial	42.9	41.4	43.7	45.5	19.2	50.9	55.1	58.1	61.0	63.6
	Residential	30.2	34.9	35.3	33.9	12.8	29.7	27.0	23.9	21.0	18.5
	Transport	18.9	16.8	13.8	13.0	5.0	11.0	9.0	8.6	8.1	7.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
121	Agricultural	0.5	0.4	0.4	0.3	60.0	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.8	7.2	3.0	8.0	8.6	9.1	9.5	9.9
	Industrial	42.9	41.3	43.3	45.4	19.2	50.9	54.7	57.8	60.8	63.4
	Residential	30.2	34.9	35.0	33.8	12.9	29.7	26.8	23.8	21.0	18.4
	Transport	18.9	16.9	14.6	13.3	5.0	11.0	9.6	9.0	8.4	8.0
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
131	Agricultural	0.5	0.4	0.4	0.3	60.0	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.8	7.2	3.0	8.0	8.6	9.1	9.5	9.9
	Industrial	42.9	41.3	43.3	45.4	19.2	51.1	54.9	57.9	61.0	63.5
	Residential	30.2	34.9	35.0	33.9	12.9	29.8	26.9	23.8	21.0	18.4
	Transport	18.9	16.9	14.5	13.2	4.8	10.7	9.4	8.8	8.2	7.9
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
112	Agricultural	0.5	0.4	0.4	0.3	59.9	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.8	7.2	3.0	8.0	8.6	9.1	9.5	9.9
	Industrial	42.9	41.3	43.4	45.4	19.2	51.0	55.0	58.0	61.0	63.6
	Residential	30.2	34.9	35.1	33.9	12.8	29.7	26.9	23.9	21.0	18.4
	Transport	18.9	16.9	14.4	13.3	5.0	11.0	9.2	8.7	8.2	7.8
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
113	Agricultural	0.5	0.4	0.4	0.3	59.8	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.8	7.1	3.0	8.0	8.6	9.1	9.6	10.0
	Industrial	42.9	41.3	43.3	45.2	19.2	50.8	55.2	58.3	61.2	63.8
	Residential	30.2	34.9	35.0	33.7	12.8	29.7	27.0	24.0	21.1	18.5
	Transport	18.9	16.9	14.5	13.6	5.2	11.2	8.9	8.3	7.9	7.5
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table B.2. Share of sectors in total energy consumptions by scenarios (%) cont.

Scenario	Sector	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
122	Agricultural	0.5	0.4	0.4	0.3	60.0	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.8	7.2	3.0	8.0	8.6	9.1	9.5	9.9
	Industrial	42.9	41.3	43.4	45.4	19.2	51.2	55.0	58.1	61.1	63.6
	Residential	30.2	34.9	35.1	33.9	12.9	29.9	26.9	23.9	21.1	18.5
	Transport	18.9	16.9	14.3	13.2	4.9	10.6	9.1	8.6	8.1	7.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
123	Agricultural	0.5	0.4	0.4	0.3	59.9	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.8	7.1	3.0	8.0	8.6	9.1	9.5	9.9
	Industrial	42.9	41.3	43.3	45.2	19.2	50.8	55.2	58.2	61.1	63.7
	Residential	30.2	34.9	35.0	33.7	12.8	29.6	27.0	23.9	21.1	18.5
	Transport	18.9	16.9	14.5	13.6	5.2	11.3	8.9	8.4	8.0	7.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
132	Agricultural	0.5	0.4	0.4	0.3	60.0	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.8	7.2	3.0	8.1	8.6	9.1	9.6	9.9
	Industrial	42.9	41.3	43.4	45.5	19.2	51.3	55.1	58.2	61.1	63.6
	Residential	30.2	34.9	35.1	33.9	12.9	30.0	27.0	24.0	21.1	18.5
	Transport	18.9	16.9	14.3	13.1	4.8	10.3	8.9	8.4	8.0	7.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
133	Agricultural	0.5	0.4	0.4	0.3	59.9	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.8	7.1	3.0	8.0	8.7	9.1	9.6	9.9
	Industrial	42.9	41.3	43.3	45.3	19.2	50.9	55.2	58.2	61.1	63.7
	Residential	30.2	34.9	35.0	33.8	12.8	29.8	27.0	24.0	21.1	18.5
	Transport	18.9	16.9	14.5	13.5	5.0	11.0	8.8	8.4	8.0	7.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
212	Agricultural	0.5	0.4	0.4	0.3	60.0	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.8	7.2	3.0	8.0	8.6	9.1	9.5	9.9
	Industrial	42.9	41.4	43.5	45.4	19.2	51.0	55.0	58.0	61.0	63.6
	Residential	30.2	34.9	35.1	33.9	12.8	29.8	26.9	23.9	21.0	18.4
	Transport	18.9	16.8	14.2	13.2	5.0	10.8	9.2	8.7	8.2	7.8
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
213	Agricultural	0.5	0.4	0.4	0.3	59.8	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.8	7.1	3.0	8.0	8.6	9.1	9.6	10.0
	Industrial	42.9	41.4	43.4	45.3	19.2	50.8	55.2	58.3	61.2	63.8
	Residential	30.2	34.9	35.1	33.7	12.8	29.6	27.0	24.0	21.1	18.5
	Transport	18.9	16.8	14.3	13.5	5.2	11.3	8.9	8.3	7.9	7.5
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
312	Agricultural	0.5	0.4	0.4	0.3	60.0	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.9	7.2	3.0	8.0	8.6	9.1	9.5	9.9
	Industrial	42.9	41.4	43.7	45.5	19.2	51.1	55.0	58.1	61.0	63.6
	Residential	30.2	34.9	35.3	33.9	12.9	29.8	26.9	23.9	21.0	18.4
	Transport	18.9	16.8	13.8	13.0	4.9	10.8	9.2	8.7	8.2	7.8
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table B.2. Share of sectors in total energy consumptions by scenarios (%) cont.

Scenario	Sector	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
313	Agricultural	0.5	0.4	0.4	0.3	59.9	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.9	7.1	3.0	8.0	8.6	9.1	9.6	10.0
	Industrial	42.9	41.4	43.7	45.4	19.2	50.9	55.2	58.3	61.1	63.8
	Residential	30.2	34.9	35.3	33.8	12.8	29.7	27.0	24.0	21.2	18.5
	Transport	18.9	16.8	13.7	13.3	5.1	11.1	8.9	8.4	7.9	7.5
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
221	Agricultural	0.5	0.4	0.4	0.3	60.0	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.8	7.2	3.0	8.0	8.6	9.1	9.6	9.9
	Industrial	42.9	41.4	43.5	45.6	19.2	51.1	55.1	58.0	61.1	63.6
	Residential	30.2	34.9	35.1	34.0	12.9	29.9	27.0	23.9	21.1	18.4
	Transport	18.9	16.8	14.2	13.0	4.8	10.7	9.0	8.7	8.0	7.8
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
231	Agricultural	0.5	0.4	0.4	0.3	60.1	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.8	7.2	3.0	8.0	8.6	9.1	9.5	9.9
	Industrial	42.9	41.4	43.5	45.6	19.2	51.1	55.0	58.1	61.1	63.6
	Residential	30.2	34.9	35.1	34.0	12.9	29.9	27.0	23.9	21.1	18.4
	Transport	18.9	16.8	14.2	12.9	4.8	10.6	9.1	8.6	8.0	7.8
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
321	Agricultural	0.5	0.4	0.4	0.3	60.0	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.9	7.2	3.0	8.0	8.6	9.1	9.6	9.9
	Industrial	42.9	41.4	43.8	45.6	19.2	51.1	55.2	58.3	61.1	63.6
	Residential	30.2	34.9	35.3	34.0	12.9	29.8	27.0	24.0	21.1	18.5
	Transport	18.9	16.9	13.6	12.9	4.9	10.8	8.8	8.3	7.9	7.8
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
331	Agricultural	0.5	0.4	0.4	0.3	60.0	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.9	7.2	3.0	8.0	8.7	9.1	9.6	10.0
	Industrial	42.9	41.4	43.8	45.7	19.2	51.2	55.3	58.4	61.2	63.7
	Residential	30.2	34.9	35.3	34.0	12.9	29.9	27.1	24.0	21.1	18.5
	Transport	18.9	16.9	13.6	12.7	4.8	10.6	8.7	8.2	7.8	7.6
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
222	Agricultural	0.5	0.4	0.4	0.3	60.0	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.8	7.2	3.0	8.0	8.6	9.1	9.5	9.9
	Industrial	42.9	41.4	43.5	45.5	19.2	51.2	55.1	58.1	61.0	63.6
	Residential	30.2	34.9	35.1	33.9	12.9	29.9	26.9	23.9	21.0	18.5
	Transport	18.9	16.8	14.2	13.1	4.9	10.6	9.1	8.5	8.1	7.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
223	Agricultural	0.5	0.4	0.4	0.3	59.9	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.8	7.1	3.0	8.0	8.6	9.1	9.6	9.9
	Industrial	42.9	41.4	43.4	45.3	19.2	50.8	55.2	58.2	61.1	63.7
	Residential	30.2	34.9	35.0	33.7	12.8	29.6	27.0	23.9	21.1	18.5
	Transport	18.9	16.8	14.4	13.5	5.1	11.3	8.9	8.4	8.0	7.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table B.2. Share of sectors in total energy consumptions by scenarios (%) cont.

Scenario	Sector	2006	2011	2016	2021	2026	2031	2036	2041	2046	2051
232	Agricultural	0.5	0.4	0.4	0.3	60.1	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.8	7.2	3.0	8.1	8.6	9.1	9.6	9.9
	Industrial	42.9	41.4	43.5	45.5	19.2	51.3	55.1	58.2	61.1	63.6
	Residential	30.2	34.9	35.1	34.0	12.9	30.0	27.0	24.0	21.1	18.5
	Transport	18.9	16.8	14.1	13.0	4.8	10.3	8.9	8.4	8.0	7.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
233	Agricultural	0.5	0.4	0.4	0.3	59.9	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.8	7.1	3.0	8.0	8.7	9.1	9.6	9.9
	Industrial	42.9	41.4	43.4	45.3	19.2	51.0	55.2	58.2	61.1	63.7
	Residential	30.2	34.9	35.1	33.8	12.9	29.8	27.0	24.0	21.1	18.5
	Transport	18.9	16.8	14.3	13.4	5.0	10.9	8.8	8.4	8.0	7.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
322	Agricultural	0.5	0.4	0.4	0.3	60.0	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.9	7.2	3.0	8.0	8.6	9.1	9.5	9.9
	Industrial	42.9	41.4	43.8	45.6	19.2	51.2	55.1	58.2	61.0	63.6
	Residential	30.2	34.9	35.3	34.0	12.9	29.9	27.0	23.9	21.0	18.4
	Transport	18.9	16.8	13.6	12.9	4.9	10.6	9.0	8.5	8.1	7.8
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
323	Agricultural	0.5	0.4	0.4	0.3	59.9	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.9	7.2	3.0	8.0	8.7	9.1	9.6	10.0
	Industrial	42.9	41.4	43.8	45.4	19.2	51.1	55.2	58.3	61.2	63.8
	Residential	30.2	34.9	35.4	33.9	12.8	29.8	27.0	24.0	21.1	18.5
	Transport	18.9	16.8	13.6	13.2	5.0	10.8	8.8	8.3	7.8	7.5
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
332	Agricultural	0.5	0.4	0.4	0.3	60.1	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.9	7.2	3.0	8.1	8.7	9.1	9.6	9.9
	Industrial	42.9	41.4	43.8	45.7	19.2	51.3	55.2	58.3	61.1	63.7
	Residential	30.2	34.9	35.4	34.1	12.9	30.0	27.1	24.0	21.1	18.5
	Transport	18.9	16.9	13.5	12.7	4.8	10.3	8.7	8.3	7.9	7.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
333	Agricultural	0.5	0.4	0.4	0.3	60.0	0.3	0.3	0.3	0.3	0.2
	Commercial	7.6	6.5	6.9	7.2	3.0	8.1	8.7	9.1	9.6	10.0
	Industrial	42.9	41.4	43.8	45.5	19.2	51.3	55.3	58.3	61.2	63.8
	Residential	30.2	34.9	35.4	34.0	12.9	29.9	27.1	24.0	21.1	18.5
	Transport	18.9	16.8	13.5	13.0	5.0	10.4	8.7	8.3	7.8	7.5
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

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